TCRP
SYNTHESIS 38

TRANSIT
COOPERATIVE
RESEARCH
PROGRAM

Sponsored by
the Federal
Transit Administration

Electronic Surveillance Technology on Transit Vehicles

A Synthesis of Transit Practice

TRANSPORTATION RESEARCH BOARD

NATIONAL RESEARCH COUNCIL

TRANSIT COOPERATIVE RESEARCH PROGRAM

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Public Transit

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TRANSPORTATION RESEARCH BOARD — NATIONAL RESEARCH COUNCIL

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transit Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of vice configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at anytime. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end-users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Special Notice

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PREFACE

A vast storehouse of information exists on many subjects of concern to the transit industry. This information has resulted from research and from the successful application of solutions to problems by individuals or organizations. There is a continuing need to provide a systematic means for compiling this information and making it available to the entire transit community in a usable format. The Transit Cooperative Research Program includes a synthesis series designed to search for and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in subject areas of concern to the transit industry.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff Transportation Research Board

This synthesis will be of interest to transit agency professionals, consultants who work with them, as well as vendors, in dealing with on-board vehicle surveillance technologies. The report describes the state of the practice concerning the use of on-board vehicle surveillance technologies designed to address both safety and security issues at public transportation agencies. It includes a review of emerging technologies likely to be implemented in the near future in the transit environment. Issues and shortcomings with surveillance are addressed, including financial, legal, maintenance, and procedural concerns. This document touches on the successes and failures of systems in meeting both system needs and product descriptions.

Administrators, practitioners, and researchers are continually faced with issues or problems on which there is much information, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered or not readily available in the literature, and, as a consequence, in seeking solutions, full information on what has been learned about an issue or problem is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the issue or problem. In an effort to correct this situation, the Transit Cooperative Research Program (TCRP) Synthesis Project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit issues and problems and synthesizing available information. The synthesis reports from this endeavor constitute a TCRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to a specific problem or closely related issues.

This document from the Transportation Research Board integrates information from a review of applicable literature and ongoing research and applications of surveillance technologies used on transit vehicles and survey responses from selected transit agencies, supplemented by discussions with product vendors, transit agency representatives, and industry experts.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, available information was assembled from numerous sources,

including a number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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Christopher W. Jenks, Manager, Transit Cooperative Research Program, assisted TCRP staff in project review.

Information on current practice was provided by many transit agencies. Their cooperation and assistance was most helpful.

ELECTRONIC SURVEILLANCE TECHNOLOGY ON TRANSIT VEHICLES

SUMMARY

This synthesis describes the state of the practice concerning on-board vehicle surveillance technologies, including transit agencies' experiences, the findings of a literature search, and a review of existing and emerging technologies designed for use in the transit environment.

Information presented is as inclusive as possible. The basic technology is applicable to both bus and rail vehicles. However, survey responses received for this report are more universally for bus installations. Recording devices, based on analog and digital technology, are available to capture audio data, video information, and records of vehicle sensor readings. Currently, although analog recorders are still the primary means of providing permanent records for the surveillance market *as a whole*, far more widespread use of digital technologies can be seen in the *transit industry*, with 17 of 23 respondents reporting that their agencies use digital equipment. Digital recording devices for use in all applications in the closed circuit television industry were introduced in the early 1990s, with scores of manufacturers offering digital recording or storage devices. The devices remain a new technology in the industry and as applied to on-board use.

Agencies deciding to install surveillance equipment must select among various types of systems, including video equipment, digital event recorders that can capture and store both video and audio information, as well as vehicle sensor data such as speed, braking, and turn signal activation; and audio systems, recording sound events with the vehicle. Each system has its benefits and drawbacks. Moreover, each has an array of features, such as camera configuration, lens types, recording equipment, and storage media, which must be evaluated by transit agencies making the purchase. Equipment specifications are explained along with the implications of equipment selections in terms of system performance in order to assist agencies in making informed decisions regarding equipment.

Surveillance systems have been installed in the transit environment for various reasons, including the following applications cited during the literature search, questionnaire, and follow-up phases; crime prevention and response, risk management, legal evidence, response to events in progress, customer service, and employee security. All but one agency responding to the survey would recommend a surveillance system to another similar agency considering such a system. Although the benefits of surveillance technology are considerable, some issues do exist. For example, system costs, maintenance requirements, and liability and privacy concerns may limit the utility of recording devices or constrain their use to specific situations.

CHAPTER ONE

INTRODUCTION

On a typical weekday, as many as 13 million people in the United States ride transit (*1*). Passengers use the nation's fleet of buses, demand response vehicles, ferry boats, heavy rail vehicles, light rail vehicles, trolley buses, and other vehicles (*2*), and transit agencies operating these vehicles are charged with ensuring, to the extent feasible, that the public transportation environment is secure and safe.

Design solutions and patrol tactics have been implemented, with varying degrees of success, to safeguard the security of passengers, transit employees, and system property. In addition, strategies have been designed to address the isolation and resulting lack of security that passengers, as well as operators, perceive in the absence of direct police or security personnel contact on transit vehicles. A few transit systems are able to rely on a resource-intensive patrol strategy to address both crime and the perception of crime. For example, the Metropolitan Atlanta Rapid Transit Authority (MARTA) assigns transit police officers to each train in operation from 3 p.m. to 11 p.m. Sundays through Fridays, and from 5:00 p.m. to 1:00 a.m. on Saturdays, supplemented by random patrols during other times of the day (*3*). Such a disbursement of personnel resources, however, is not feasible for most agencies in an environment in which hundreds or even thousands of vehicles carry passengers. Fewer than 10 percent of agencies maintain a full-time, in-house security or police presence (*4*), and a limited number of agencies make use of a dedicated contingent of city police, such as in New York and Chicago.

In recent years, agencies have concentrated on improving the actual and perceived security of transit facilities, such as subway stations and bus depots, through concepts such as Crime Prevention through Environmental Design (CPTED). CPTED is based on the theory that through the design of facilities and communities, architects, city planners, and security and law enforcement officials can produce a climate of security by creating a physical environment that positively influences human behavior (*5*).

The assurance of both actual and perceived security on transit *vehicles*, however, is complicated by several factors, which are present to a lesser degree in facilities. Facilities, as compared with transit vehicles, are more centralized, constitute a relatively controlled environment, can be designed with security in mind, and offer locations where concentrations of personnel and technology resources can be utilized relatively efficiently.

Though most serious *security* issues occur in transit *facilities* or transit-related facilities such as stations or parking lots (Table 1; ref. *6*) rather than in vehicles, patrons often do not perceive vehicles to be secure.

TABLE 1
CRIME OCCURRING IN TRANSIT ENVIRONMENT

Crime	Occurring in Vehicle	Not Occurring in Vehicle
Homicide	10	13
Forcible rape	7	40
Robbery	540	3,144
Aggravated assault	1,040	1,274
Larceny/theft	2,167	9,213
Motor vehicle theft	NA	2,197
Burglary	24	467
Arson	17	43

Source: FTA, 1988 *National Transit Database* (*6*).
Note: NA = not available.

Passengers often perceive that their personal mobility is limited on board transit vehicles, where large deployments of security, police, operational personnel, and other system resources are difficult to maintain in the same way resources can be concentrated in centralized facilities (*7*). Technology-assisted surveillance strategies, such as closed circuit television (CCTV), have been widely used to support transit personnel in addressing passenger and employee safety, security, and perceived security in transit facilities. Examples of agencies that rely on CCTV systems within facilities include the Washington Metropolitan Area Transit Authority (*8*), which uses CCTV to improve visibility and deter "quality of life" crimes; Los Angeles's Metro Blue Line light rail, in which surveillance is used at ticket vending machines; and Port Authority Trans Hudson commuter rail stations in New York and New Jersey (*7*).

Until relatively recently, surveillance technology could not be used in a mobile environment to support the provision of security and safety on *vehicles*. However, as this technology has migrated toward use on vehicles, recording capabilities have improved significantly, multiple cameras can be used to more completely monitor the inside and outside of vehicles, and systems promising lower maintenance and downtime have been introduced.

Consequently, transit systems are now evaluating and purchasing audio and video surveillance equipment for vehicle installation. In addition, vendors now offer new vehicles with surveillance equipment as an option. Although results are not generally quantified, electronic surveillance is thought by many agencies making use of the equipment to be both beneficial and cost-effective. Transit agencies responsible for millions of passenger trips annually have installed such equipment. Transit systems in Chicago, Philadelphia, San Francisco, Cleveland, Portland, Buffalo, and Sacramento, for example, use CCTV cameras within vehicles (*9*).

OBJECTIVES

This synthesis describes the state of the practice with regard to the use of on-board surveillance technologies designed to address both safety and security issues at public transportation agencies, including a review of emerging technologies likely to be implemented in the near future in the transit environment. The objectives of this synthesis are as follows:

- To examine, to the extent possible, the objectives of agencies in selecting and implementing surveillance technologies;
- To describe technologies that have been implemented to meet these objectives;
- To detail available and evolving system configurations and choices; and
- To document current practices and future needs in this area for transit agencies considering the procurement and use of electronic surveillance equipment.

This synthesis includes a discussion of the nature and extent of the use of on-board electronic surveillance technology, a discussion of the benefits associated with the technology, best practices and recommendations from the transit agencies, institutional issues, and legal concerns, as well as information on technology configurations and evolving trends in the industry. Furthermore, this document touches on the successes or failures of systems in meeting both system needs and product descriptions.

METHODOLOGY

A review of applicable literature and ongoing research and applications of surveillance technologies used on transit vehicles was performed, including an extensive on-line search, drawing from industry, legal, business, university, and government databases. This effort included an examination of electronic surveillance equipment, a study of the literature to learn of surveillance strategies in place, and a review of the technologies used in similar applications. The scope of the literature search included both the public transit industry and related fields that share fundamental similarities. A list of agencies using surveillance technology was developed through the literature search and was supplemented through discussions with product vendors, transit agency representatives, and industry experts.

Subsequently, a questionnaire (see Appendix A) covering the following topics was developed and sent to transit agencies believed to be using or considering the use of surveillance technology on transit vehicles:

- Agency operations
- Details on equipment in use
- System application and effectiveness
- Procedures in place for the management of technology
- Legal considerations
- Costs
- Issues with implementation
- Agency recommendations.

Responses were reviewed, evaluated, and tabulated, and follow-up telephone calls were made to clarify responses and to obtain more detailed information. Appendix B contains survey responses, and Appendix C a list of responding agencies. Copies of reports, policy statements, and other documentation that detailed particular areas of interest likely to be generally applicable to the industry as a whole were requested from respondents. Also, other industry experts (in addition to the questionnaire respondents) were consulted for detailed information, including product vendors and legal experts. Finally, literature review, questionnaire, and interview results were consolidated, analyzed, and detailed in this report.

QUESTIONNAIRE PARTICIPANTS

The questionnaire was distributed to transit agencies of varying sizes, supplying different modes of service, and located in all geographic areas of the United States, providing insight on the types of equipment used in transit surveillance and the successes and failures experienced with this technology. Thirty-two agencies completed questionnaires. Of these 32 agencies, 26 reported having surveillance systems in operation. Some agencies had plans in place to implement surveillance equipment, although the systems were not yet in operation; some agencies had only pilot or beta-test versions in place. For example, the Metropolitan Transit Authority of Harris County operating in Houston, Texas, although not using a surveillance system when surveyed, had plans to pilot a CCTV system on six buses at a cost of approximately $12,000 per vehicle installation.

Fourteen of the 30 largest transit agencies in the United States completed questionnaires. Thirty respondents

provide bus service, 6 operate heavy rail service, and 11 provide light rail service. These transit agencies together carry nearly 2.5 billion passengers annually, utilize a combined fleet size of more than 24,000 vehicles, operate in 17 states plus the District of Columbia, and serve rural, large urbanized, and medium-size urbanized areas. In 1999, these agencies provided more than 28 percent of all daily passenger transit trips and operated over 29 percent of all transit vehicles in the United States (*2*).

ORGANIZATION

Chapter 2 provides background on the technologies currently available for electronic surveillance on vehicles. Components and issues such as cameras, recording devices, and technology standards are discussed. Chapter 3 describes the extent of surveillance technology use on vehicles in the transit environment. Types of technologies, location and quantities of surveillance devices in place, various applications and maintenance and other procedures are also discussed. Chapters 4 and 5, together, provide a framework for the discussion of both the benefits and the costs (financial and otherwise) of surveillance technology as implemented on transit vehicles. Application of the technology to reducing crime levels, increasing perceived security, and limiting fraudulent claims is described. In addition, issues with the implementation of the technology, such as legal concerns, technology costs, and maintenance requirements, are explored.

Chapter 6, which contains recommendations for further actions to improve the state of the practice, concludes this report. Seven appendixes provide supplemental information to support practices identified in this report.

CHAPTER TWO

SYSTEM DESIGN AND DESCRIPTION OF EXISTING SURVEILLANCE TECHNOLOGY

Multiple technological choices are available for achieving mobile surveillance on vehicles. These technologies can be grouped into three major types, each of which is discussed in this chapter.

- CCTV systems
- Event recorders
- Audio surveillance

Most agencies responding to the survey made use of CCTV systems in surveillance (Figure 1), with an almost equal number of agencies using event recorders, and far fewer agencies using audio surveillance. Unfortunately, because transit agencies are fundamentally local organizations, many tend to work in relative isolation and do not widely compare experiences, such as the benefits and drawbacks of various surveillance systems and configurations. As a consequence, many agencies rely primarily on information supplied by vendors in selecting and installing these surveillance systems. This synthesis provides a means for distribution of applicable and transferable information to assist the transit industry as a whole.

Agencies selecting these systems are confronted with many choices of equipment features, configurations, and options. This chapter defines systems and system components to assist transit agencies in making the equipment choices that will best suit their needs, including technological trade-offs, such as choice of formats, storage capabilities, and data transmission. A glossary is included at the end of this report for reference regarding particular equipment components and terminology. Appendix D contains more detail on some of the equipment choices detailed in this chapter.

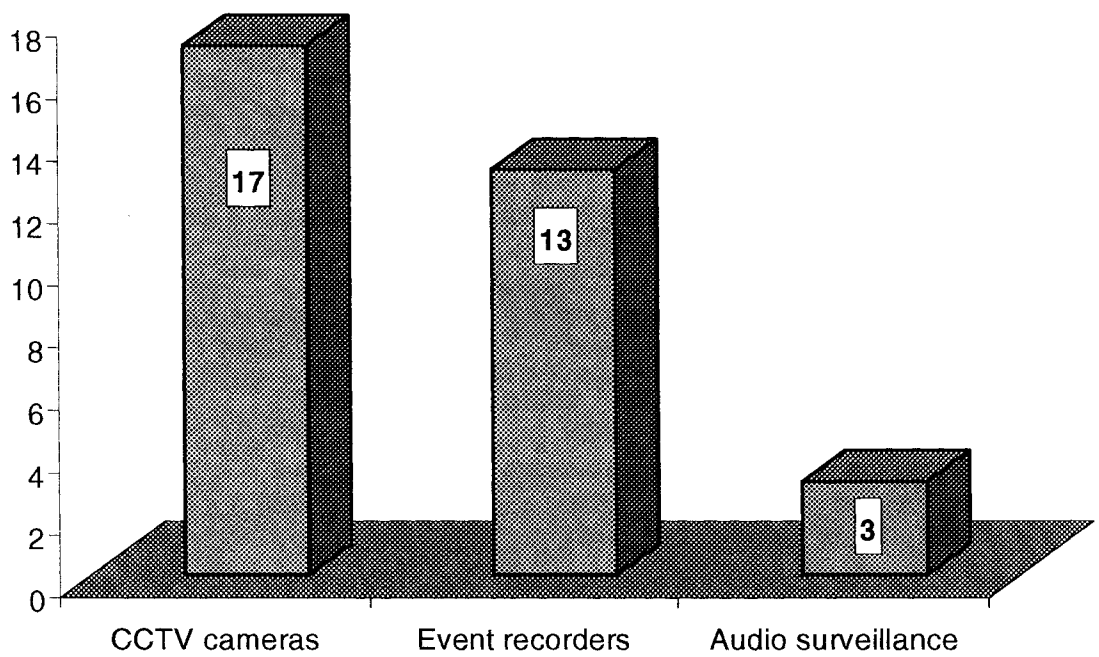


FIGURE 1 Use of surveillance types.

SYSTEM DESIGN: CLOSED CIRCUIT TELEVISION

Although multiple formats exist, most CCTV systems can be broken down into the following, basic components:

- Lens
- Camera
- Transmission link
- Multiplexer
- Video recording devices

Lens

A camera lens collects information reflected from a scene, such as the inside or outside of a vehicle, and forms an image on a light sensitive camera by directing and focusing this reflected light. Lighting levels in the intended area of coverage, subject size, and subject distance from the camera normally dictate lens choices.

The use of CCTV on board transit vehicles takes advantage of the fact that cameras are mounted at a fixed location, with a predetermined field of view. In choosing a system, it is important to select lenses appropriately for the fixed features of the scene to be captured (*10*).

- *Focal length*—The focal length of a lens is the distance from the center of the lens to the point at which parallel rays from a distant subject come to a common focal point. The focal length, along with the size of the object and the distance to the lens, determines the size of the image created. Lenses with a short focal length (for example, 8 to 20 mm) are normally used for wide-angle pictures. Lenses with long focal lengths (80 to 300+ mm), telephoto lenses, are used for distant subjects. For transit vehicles, a medium focal length is appropriate.

- *Field of view*—The field of view is a measure of how much of the subject and the immediate surroundings will be filmed, selected to encompass the length and width of the vehicle.

Unfortunately, lighting levels are not constant in the transit vehicle and equipment must be selected to be compatible with a range of conditions (*10*).

- *Lens diameter*—Lens diameter, or aperture, affects the ability of the lens to gather light and, therefore, operate at various lighting levels. Larger diameter lenses are more suitable for low-lighting situations. The iris (either fixed diameter or variable) controls the amount of light entering the lens, and variable lenses are rated at the largest diameter. For transit applications, electronic iris cameras can be used, but for quality performance auto-iris lenses are preferred, given lighting fluctuations.

- *F-stop rating*—The lens' f-stop rating is the ratio of the focal length of the lens to its diameter (with the iris fully open). The smaller the f-rating, the more light the lens can absorb. A low f-number is needed when a scene has low light. High f-numbers operate well in bright sunlight. A lens with a 50-mm focal length that had a diameter of 35.7 mm would have the rating of f-1.4 and would operate fairly well in low light situations. An f-22 rating would be appropriate for bright sunlight conditions.

Camera

CCTV camera sensor electronics convert the amplified, visible image from the lens into an equivalent electrical signal, suitable for transmission to a recording device. This conversion is normally accomplished by means of a light-sensitive charge-coupled device (CCD) camera, which uses a semiconductor to generate variable signals based on the levels of light focused on it. Focused light from the lens creates electrical charges that are then transmitted to an amplifier. Cameras that generate either an analog or a digital signal are available, and examples of each can be found at agencies that responded to the questionnaire (*11*).

One choice that a purchasing agency must make is the type of image pickup used in the surveillance device. The type used is listed in the system's technical specifications. Cameras equipped with electron tubes as pickups are available, but are being replaced by CCD devices. The vast majority of cameras with a resolution of up to 400 lines use CCDs, which are less expensive to produce for low-resolution [video home system (VHS) comparable] or medium-resolution (Super VHS) applications. Until recently, only tube cameras were able to generate high resolutions (greater than 500 lines). Since 1998, however, CCD cameras have been offered that match this level of resolution (*10*).

Higher levels of lighting, in general, produce better quality images, with CCD devices tending to handle low lighting situations better than tube cameras. Special CCD devices that operate in bright sunlight are also available. Solid-state devices (CCD) have the ability to simulate a shutter with an adjustable speed by obtaining information from an entire image at the same time, whereas a tube camera scans through a scene to provide a consistent image. The ability of CCD devices to register an image simultaneously allows for the use of a shutter and thus the capture of still-frame scenes (*10*).

Another important consideration for a transit agency is the choice between systems that provide a signal that can

reproduce or display full-color pictures or one that is limited to black and white images. Systems producing color images are more costly, yet are often capable of producing evidence in which identification of individuals is more accurate. Cameras producing color images, however, are generally less light sensitive (i.e., require more lighting to generate a clear image) than those producing black and white images. Black and white cameras, therefore, may be preferable in certain low lighting situations.

Because the costs of surveillance technology have dropped sharply over the past decade, more agencies are installing systems capable of color imaging. Twelve of the 21 agencies responding to the survey question asking about camera features stated that they used cameras capable of generating color images. Agencies such as Portland Tri-Met have upgraded to color systems from black and white, which did not produce images of adequate visual clarity (*12*).

Analog Cameras

Analog cameras are designed to convert visual information to an analog signal that may be displayed in real-time on a monitor, recorded on a storage device [a video cassette recorder (VCR)], or both. The signal generated consists of individual frames of image information, captured at a rate per second that is dependent on the equipment selected. Higher rates demand more storage capacity, yet enable collection of more detailed information (*11*).

Digital Cameras

Similar to analog cameras, digital cameras convert image information into data that may be displayed, stored for later use, or both, but produce a signal compatible with *digital* displays or recorders. Digital surveillance systems address some of the more significant information storage and retrieval issues inherent in analog systems. Digital signals enable exact copies to be made. In addition, digital video signals do not experience signal "noise," limiting signal degradation over distance or in the presence of a weak or noisy signal, but resulting in signal dropout under certain circumstances (*10*). In addition, the use of digital technology offers advantages over reliance on analog storage devices, which will be discussed in further detail later in this chapter.

Transmission Link

Both analog and digital cameras generate an electrical video signal representing the scene image, which must be relayed to another device by some means of transmission. This transmission may involve moving data only as far as a storage device located on the vehicle, or data may be transmitted wirelessly to one or more centralized monitoring areas.

Technological advances over the past few years have allowed for more flexible, real-time transmission of images and sounds from on board vehicles to outside locations. Though not used by many transit agencies, the technology does offer the potential to enhance response to serious incidents in progress, such as terrorist events. For example, the Massachusetts Bay Transportation Authority (MBTA) uses an analog CCTV camera system in conjunction with a radio frequency transmitter that allows MBTA police to monitor transit vehicle activity from a trailing vehicle. The utility of surveillance systems is further enhanced for this purpose when used in conjunction with other technologies, such as global positioning systems, to locate transit vehicles.

Certain recent changes in telecommunications standards, such as improved video coding and decoding algorithms and standards, as well as new bandwidth efficiency requirements mandated by the Federal Communications Commission (FCC), have enhanced the feasibility of wireless transmission of images to remote locations for real-time review. The FCC's adoption of standards requiring faster data transmission rates makes more digital bandwidth available, allowing for the transmission of quality video images over wireless links such that activities on board vehicles can be viewed in real time (*9*). MBTA uses a 2.4 GHz frequency for its wireless transmissions of video information.

Trade-offs exist with this type of transmission; FCC wide-band licenses are difficult to obtain in some geographic areas, the transmission of real-time images results in a significant current drain, and equipment is costly (personal communication, B. Porter, Metro Transit, St. Paul, Minn.).

Multiplexer

In multiple camera setups, multiplexers are used to collect signals from a number of cameras and record them almost simultaneously onto a storage device (*11*). Multiplexers provide a cost-effective means of transmitting images generated by multiple cameras. Multiplexers can display a matrix of images onto one monitor to allow several cameras to be viewed simultaneously in real time or on a delay. In addition, this process allows one cable to be used to transmit data from multiple cameras.

Signals are added from a fixed number of cameras so that transmission on a single cable can be achieved with

signal separation performed by a multiplexer at the other end. This second unit can be configured to sort and display only the desired data from one of several cameras, allowing a single camera to be viewed. Full frames of data are recorded, supporting higher resolution and greater utility for evidentiary purposes.

Because multiplexers "time-share" information, as more cameras are added to a system, fewer video frames are recorded per video camera. For digital systems, multi-channel digital recorders are available to record all camera frames.

Video Recording Devices

Analog Recording

In analog systems, VCRs and magnetic storage media are used to record data, with VHS cassettes being the standard media used. VHS offers a low-cost option for analog recording, although it only offers 240 lines of horizontal resolution, the lowest of available formats. Other variants of the VHS format include Super VHS, which offers a greater signal-to-noise ratio and a higher resolution (400 lines), and various tapes of smaller size produced by several manufacturers.

Commercial-grade devices implemented for this application are similar to those used in consumer applications, but with more durable features designed to accommodate continuous or near-continuous use as well as vibration, temperature fluctuations, and poor air quality. The Society of Automotive Engineers and other organizations have developed standards to support the manufacture of devices able to withstand the mobile environment. When selecting a VCR, for example, compliance with this and other applicable standards can be a decision-making factor (*13*).

Most VCRs are installed in a metal vault and secured with a key. This vault offers security protection, dust protection, and fans or other type of heating and cooling devices. Heaters are also necessary for VCRs in regions that experience severe cold, because VCRs will not operate below 55°F. The cameras are permanently mounted and the VCR may or may not have a remote control device for the driver (*13*).

Because of environmental factors that tend to shorten the life of surveillance equipment, many agencies have implemented features to protect their investment. Of the 21 agencies that answered this survey question, 18 reported using vandal-proof housings, and 13 use surge protection. A consistent power supply is often a problem, and five agencies use an alternate power supply, with a similar number using power conditioning features to protect against electrical spikes.

A typical system will begin recording automatically, from 30 to 60 seconds after the vehicle is powered up, allowing vehicle power to stabilize first. The VCR either goes directly into the recording mode or maintains a ready mode for an external trigger, such as the activation of the operator's emergency call button. The VCR will generally record for the entire time the bus remains in operation and stop recording after a similar interval when the ignition is switched off. Sixteen of 21 agencies that responded reported using a system that starts automatically (*13*). The need for automatic startup and the choice of when the system starts and stops is dependent on the intended application.

Most video systems use on-screen time and date recording. Real-time and time-lapse options are available. A time-lapse recorder differs mechanically from VCRs designed for home use, permitting the device to essentially capture snapshots of a scene at user-determined rates. Such systems can also be configured to perform real-time recording when activated manually (for example, by an operator depressing an emergency alarm). Because of the difference in data recorded by real-time versus time-lapse devices, a typical real-time recorder may be capable of recording 6 hours of video information, whereas a time-lapse system could potentially record for up to 720 hours, because of the difference in sampling speeds (*11*). In an on-board transit application, this type of recording may not be capable of collecting necessary information. Time-lapse recording may be better suited to primarily stationary applications in which scenes change slowly (e.g., parking lots).

Digital Recording

The process of recording images digitally is comprised of two stages, each performed by a digital recorder; data compression and data storage.

Data compression is a technique used to minimize transmission and storage requirements for images captured by a digital camera. Several options for compressing digital video images exist, including JPEG, MPEG, H263, Wavelet, or other methods designed by individual manufacturers. JPEG compression, established in 1974 by the Joint Photographic Expert Group, is compressed into an output consisting of a data stream. MPEG compression, established later by the Moving Picture Experts Group, uses different coding techniques yielding data transfer requirements of 1.5 Mbits per second and compression ratios of up to 60:1. File sizes produced by either technique tend to be large. As a result, a modified standard data compression technique, H263, was created specifically for the CCTV industry. This standard requires a data transfer rate from camera to recorder of only 64k bits per second.

Wavelet compression is yet another option, and uses multiple filters to yield compression ratios up to 350:1. Finally, to further compress images and decrease storage and transmission requirements, a number of filtering techniques are in use or are being developed, including spatial redundancy reduction (using correlations between neighboring pixel values), spectral redundancy reduction (based on correlation between different color planes or bands), and temporal redundancy reduction (using correlation between adjacent frames and sequence) (*14*).

Data storage is the second stage in the recording process. Unlike analog storage devices (i.e., VCRs), which record to videotape, digital recorders offer options of storage by means of computer hard drive (HHD), DAT, or DSS, tape exclusively or in combination. Typical digital disks (DVD) can accommodate 5 GB of information, computer hard drives used in the application may permit storage of approximately 40 GB of data, and digital tape systems typically have over 60 GB of capacity. Digital information, typically time and date stamped, may be retrieved in a flexible, nonsequential manner. Although systems designed to retrieve information from videotapes have nonsequential retrieval capabilities, digital systems offer enhanced flexibility in this respect, saving time in the review and application of information. Digital tape systems can be integrated with "jukebox" systems, which enable recording times to be increased significantly (*14*).

Transit agencies desiring to use a digital system currently must choose between two leading manufacturers who offer a total of eight formats. Resolution of digital cameras is generally at least 400 lines, which is equivalent to an analog Super VHS system's resolution (*10*).

Choosing Between Digital and Analog Systems

Digital recording devices for use in all applications in the CCTV industry were introduced in the early 1990s. Currently, more than 75 companies offer digital recording or storage devices; the devices remain a new technology in the industry, as applied to on-board use (*14*).

Digital images lack the "noise" present in analog signals and the concerns about analog tape quality degradation. Digital signal dropout is, however, not a concern for analog systems. Depending on a digital recorder's capabilities and configuration, higher image quality patterns can be obtained than were previously available on analog systems, allowing the user to record images at 160 by 120, 320 by 240, or 640 by 480 pixels (*14*).

Some agencies select digital systems for durability considerations. Even VCRs designed for commercial applications are inherently vulnerable to environmental factors. The Ann Arbor Transit Authority, for example, after testing multiple analog systems, eliminated from consideration those using standard VCRs only (*15*). The agency decided on a digital system that does not require the use of a VCR. The Southeastern Pennsylvania Transportation Authority (SEPTA) had a similar experience when choosing its equipment, ultimately choosing digital equipment due to durability concerns (*16*).

Retrieval of digital information can be configured, based on storage media selections, such that images can be accessed in a fraction of a second. Magnetic hard disks can achieve video storage and retrieval times of from less than 1 second to less than one-twentieth of a second for monochrome images and from between 3 seconds and one-fifth of a second for color. In contrast, VCRs require several minutes to fast forward or fast rewind when searching for a particular frame on the tape. Digital systems also require far less archival space than analog systems.

Analog technology, however, has a number of advantages. It has been in existence longer, and many transit agencies are familiar with the systems. Although digital devices have gained in popularity for mobile transit applications, analog technology remains the standard in the security industry as a whole. Many agencies choose this technology because, for their purposes, it offers adequate functionality for a lower cost. Also, many systems have infrastructure (archival methods, trained mechanics, procedures) in place to manage the technology and achieve integration with facility surveillance methods.

SYSTEM DESIGN: EVENT RECORDERS

The digital event recorder, a second type of digital recording device, is becoming more widely used on vehicles among transit agencies. Thirteen of the 24 agencies responding to a question on technology type reported using event recorders. Such a device is able to record visual images as well as signals from an array of vehicle systems. Monitoring of nonvisual information is performed similar to the monitoring of images, using sensors of on-board audio and vehicle controls. The system is generally activated through vehicle ignition, which initiates digital recording of data from cameras and preselected sensor parameters.

Sensors are connected to the event recorder or "black box," which then sends video, audio, and other information to a digital data storage device, typically a removable hard drive. In the event of an accident or a crime, the drive is retrieved and connected to a desktop or laptop computer with playback software. Products exist that are specifically designed for mobile applications and have been used in other applications, such as police vehicles. Commercial equipment is engineered for mobile applications to handle vibration, shock, extreme heat, cold, dust, and humidity.

Emergency recording features are available, allowing operators to mechanically depress an emergency button to ensure that images captured during a certain period of time are highlighted for archival. Systems can be configured such that information on the digital storage media is not overwritten if the hard drive becomes full. In general, preset maximum record times limit the period before the hard drive begins to overwrite itself. Such data protection can be initiated automatically or manually by means of an operator depressing an "event save" button. Marked or saved events are protected by the system until the system is reset. Upon review, archival or deletion of marked or saved events can be performed. Event recorders can also be configured so that a sudden stop by the vehicle automatically triggers a camera to run for 30 or 60 more minutes to record any relevant data, and then stop. On several systems, a liquid crystal display (LCD) allows for fast review of information, eliminating the need to remove the hard drive after each shift, thereby reducing maintenance costs (*15*).

Features exist to view and analyze data on board a vehicle or at any remote locations with access to the removable data drive through an external interface using a laptop computer, eliminating the time required to return to a desktop viewing station. As described previously with regard to digital recorders, event recorders can be configured to enable remote monitoring of activities on board the vehicle in real time. Wireless transmission of video information to a central facility permits such monitoring, initiated by either an operator-activated emergency button or by the monitoring facility itself (*17*). Although MBTA used a wireless transmission feature on its analog CCTV system, no agencies responding to the questionnaire reported using such a feature in conjunction with an event recorder, though systems marketed for this application can be configured with this capability.

An important consideration in selecting an event recorder system is that no industry standard exists for operating software. Without a prevailing software standard among device manufacturers, competitive bidding on alternate equipment and performing system upgrades is difficult (personal communication, B. Porter, Metro Transit, St. Paul, Minn.).

AUDIO SURVEILLANCE

Audio can constitute an important component of a vehicle surveillance system. For example, recording verbal abuse by operator to passengers, passengers to passengers, and passengers to operator assists in supporting an agency's security and safety programs (*13*). In addition, audio surveillance can be used to support the assessment of customer service training needs and policy guidance by enabling the agency to review verbal interchanges between operator and passenger.

Audio surveillance systems can be implemented as stand-alone units (systems without video surveillance systems) or as one component of a surveillance system that records sounds, images, and, in some cases, vehicle sensor information. Cameras that include built-in audio surveillance and recording functions are widely available for black and white and color CCTV cameras, as well as digital event recorders. A microphone is generally included in the same enclosure as the camera, offering a compact solution that is simple to install and is protected from the environment in the camera housing. When operating in conjunction with a video system, audio recording operates much like that performed by home video recording equipment. For analog devices, sound data are stored on videotape; for digital devices, the hard drive, DAT, or other storage media captures digital sound information.

On both stand-alone audio systems and those incorporated into video surveillance systems, additional audio pickup devices can be used. Especially in single camera systems, the physical location of the camera, and thus the microphone, at the front of the vehicle cannot record audio from passengers in the rear of the bus. Additional microphones for the rear can be used and mixed with the one up front. Systems may incorporate additional ports into the design of their equipment to allow for additional microphones.

In choosing audio equipment, product specifications for audio may include the following:

- *Audio S/N*—The signal-to-noise ratio (S/N) is a measure of signal quality that is typically measured in decibels.
- *Audio Frequency Resolution*—This specification indicates the range of frequencies the system is able to detect and record (150 Hz–8 KHz).

Legal issues concerning the use of audio surveillance, especially in conjunction with video recording, are discussed in chapter 5.

CHAPTER THREE

SYSTEM CONFIGURATION AND USE

Transit agencies find themselves at various stages of technology usage or procurement, including initial evaluation of equipment, upgrade of surveillance technology from analog to digital, or expansion of implementation to include entire fleets or different vehicle types. Surveillance systems are offered by scores of vendors with a wide variety of features. Agencies must carefully choose how to configure systems to meet their requirements. This chapter explores the extent of the use of surveillance technology on vehicles, as well as the various types of system implementations used.

SELECTIVE INSTALLATION

The first configuration choice that an agency must make is which vehicles it will equip with surveillance technology. Survey responses reflected that, often, a fraction of agency vehicles, rather than entire fleets, are outfitted with surveillance devices. Most commonly (11 of 23 agencies), respondents reported that less than 25 percent of their agency's fleet is equipped with surveillance devices (Figure 2).

In some cases, the need for surveillance does not exist for all vehicles or routes. Figure 3 details some of the most common criteria for selecting those vehicles to be outfitted with surveillance equipment if a less than complete installation is used at a transit agency.

Newer vehicles are most commonly chosen for installation. In some cases, a phased approach to adding surveillance equipment is being used, in which a surveillance system is slowly introduced to the fleet, either through retrofit or as original equipment on newly purchased vehicles. Fourteen of 22 agencies completing the survey report that new vehicles added to the agency fleet are equipped with surveillance systems. Bay Area Rapid Transit (BART) and the Chicago Transit Authority (CTA), for example, report having used this approach.

In addition, agencies install systems in response to specific crime, fraud, disorder, safety, or passenger perception issues on certain routes. For example, in the early 1990s, the Southeastern Pennsylvania Transportation Authority (SEPTA) implemented a successful surveillance system to address a number of crime and risk management issues. Based on their experience with the relatively new technology, SEPTA management recommended that a successful surveillance program should target "specific problem areas along routes selected such as peak loading points, high accident areas, and routes heavily used by (juveniles)" (*16*).

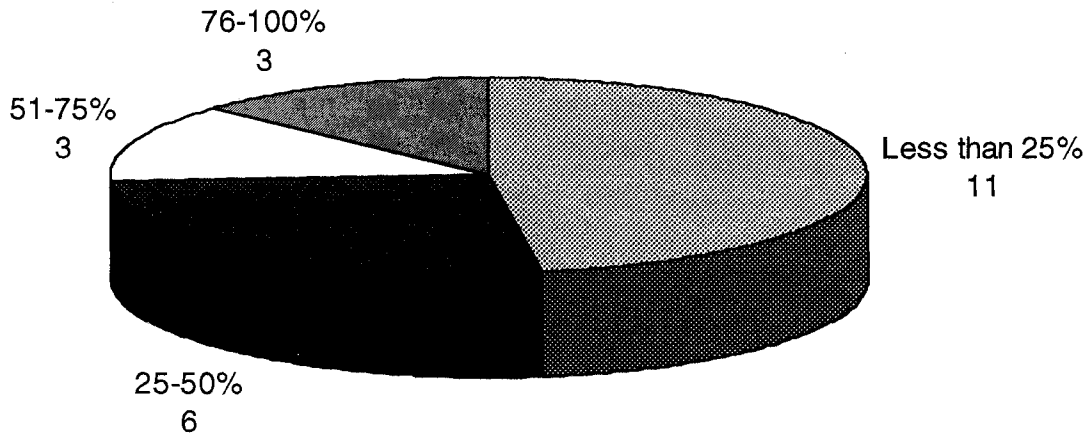


FIGURE 2 Portion of fleet equipped with surveillance systems.

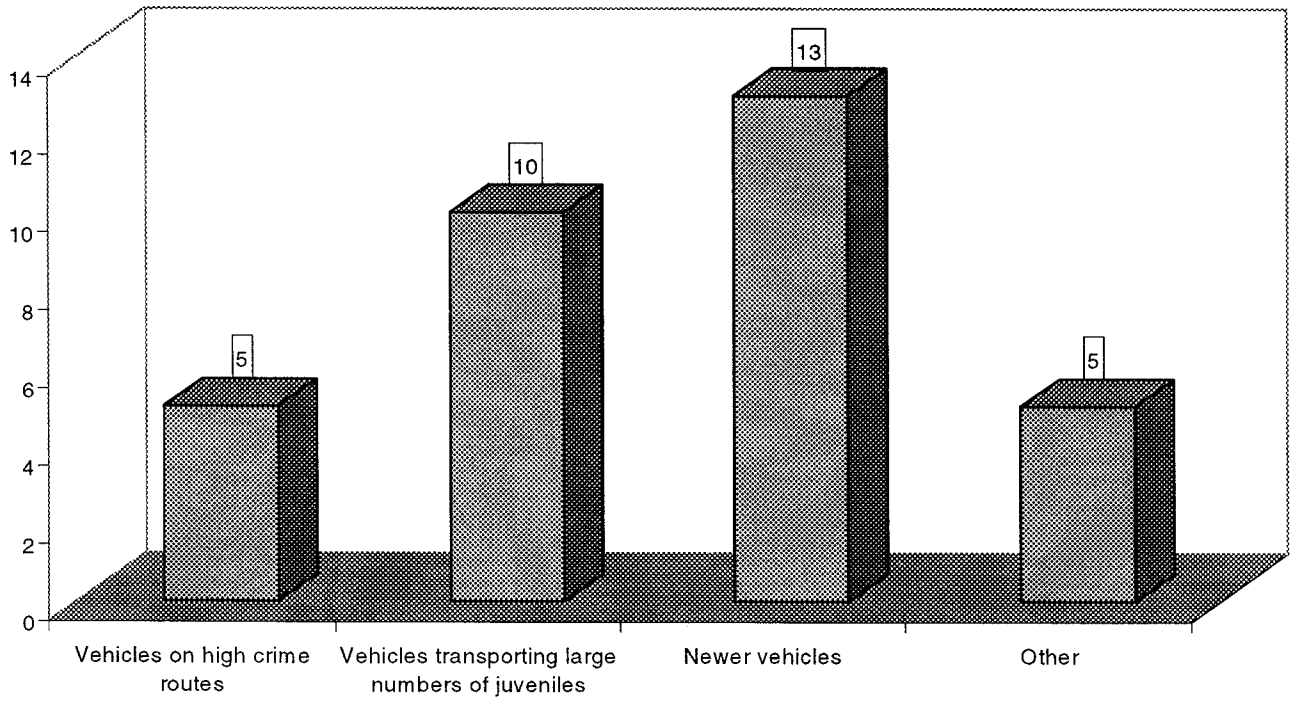


FIGURE 3 Reasons for selection of certain transit agency fleet vehicles for surveillance system installation.

SYSTEM CONFIGURATION CHOICES

Once vehicles are selected for equipment installation, choices must be made regarding equipment and camera configuration. Typically, in a single-camera system, the camera is mounted at the front of the vehicle and aligned with the aisle to capture a view of the length of the vehicle (*18*). This configuration does not require a wide-angle lens to view all passengers, but camera optics typically limit the ability to identify subjects situated in the front or rear of the vehicle. Mounting locations include above the windshield, on the ceiling, or on the vehicle header on or near the destination sign access door. A camera mounting above the windshield tends to be lower in cost, visible to patrons (which can be advantageous), and can use any standard camera. Ceiling mounts typically use dome enclosures or wedge cameras (*13*).

Two- and four-camera choices are illustrated in Figure 4 for a bus configuration. As with the single-camera configuration, the primary camera is mounted on the front header to record the length of the vehicle. In addition, a second camera is mounted on the driver-side wall to view the front doors, the front step well, and the farebox. The second camera may be activated by a signal when the door is open. In this way, recording can begin when passengers board and alight. A multiplexer manages the dual signals from the cameras to enable recording (*18*). Finally, a typical four-camera system setup is similar to the two-camera setup, but includes monitoring from the rear of the vehicle that mirrors the two-camera configuration on front. As with other multisignal setups, a multiplexer is required to manage the camera signal inputs into the VCR or other recording device.

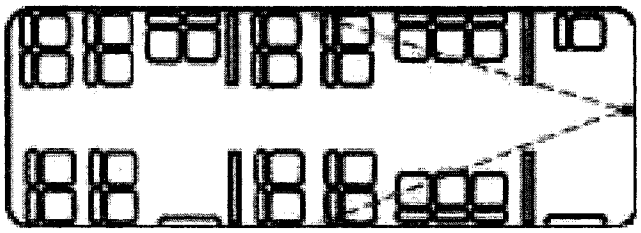
Nearly all agencies surveyed (20 of 21 responding) use multi-camera setups (Figure 5).

REPRESENTATIVE TECHNOLOGY CONFIGURATIONS

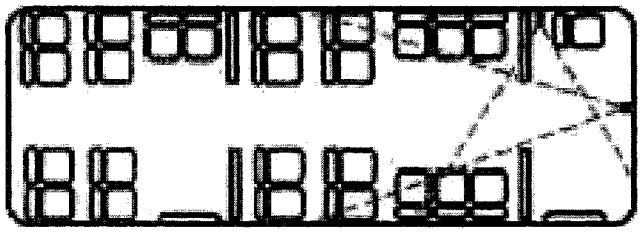
As part of the implementation of several programs involving surveillance technologies on vehicles, information has been collected in the transit industry to determine the types and levels of impact of specific surveillance projects. Crime statistics, analysis of cost savings from risk management departments, anecdotal information, and system implementation costs are useful in determining the extent to which the use of surveillance on vehicles is valuable.

Seven agencies were examined in further detail by means of the literature review and through follow-up phone calls to individual transit systems. Those agencies selected for a more detailed review represented various service area types (large versus small); systems had been installed to address different concerns (violent crime, disruptive behavior, fraud), and used various technologies (analog and digital CCTV, digital event recorders).

Single Camera System:



Two Camera System:



Four Camera System:

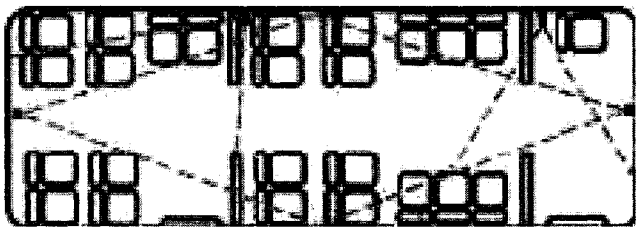


FIGURE 4 Camera configurations in single- and multiple-camera surveillance setups (*18*).

A review of the key features of several major installations, along with a summary listing that describes the principal system characteristics for each for the purpose of making cross-comparisons and that offers more detailed information on reasons for selection of technology, degrees of success achieved, and technology usage is provided here.

Buffalo, New York

CCTV partnership with Buffalo Board of Education

- Installation summary—Installation of digital cameras on the entire fleet of NFTA buses in cooperation with 15 area high schools.
- Date installed—1995.
- Type of surveillance—Review of videotapes.
- Reasons for use—Curbing disruptive and other behavior issues relating to transporting school children.
- Results—Anecdotal evidence suggests system is effective.

At Buffalo's Niagara Frontier Transportation Authority (NFTA), school transit passes allow students to ride on transit buses to and from school, requiring travel within fixed hours, use of the most direct route, and adherence to a specified code of conduct. Before the use of surveillance, NFTA's policy regarding violations of the code of conduct was to instruct the juvenile in the proper use of the transit pass. In addition, the transit passes of those repeatedly violating system rules were subject to confiscation and multiple violations prompted meetings with school and security officials on the day following the violation.

In 1995, the NFTA Transit Police installed a surveillance system to address an increase in reported incidents involving students from the public school system. A CCTV system was developed and implemented on the entire NFTA bus fleet. To support this technological remedy, the Transit Police developed a partnership based on communication with security officers at Buffalo's 15 area high schools. When behavioral problems are encountered, videotapes are taken from the bus where the incident occurred to the affected school and viewed with school security officials in order to identify those involved. This policy had a significant impact on reducing bus incidents (*19*).

Philadelphia, Pennsylvania

Digital event recording on SEPTA buses

- Installation summary—Use of digital "event recorders" on board buses.
- Date installed—Analog system installed in 1991, digital system implemented in 1995.
- Hours of surveillance—Interior of the bus is recorded while engine is running. Aisle cameras operate while bus is in motion. Door cameras operate while bus is idling.
- Type of surveillance—After-the-fact review of digital video.
- Reasons for use—Primarily designed to limit fraudulent claims and to reduce problem behavior of school children.
- Results—Believed to have reduced claims and improved security perceptions among patrons.

As recently as 1991, SEPTA annually received over 18,000 passenger claims and corresponding claims costs of $52 million. In addition, an average of $5,000 was spent each week to repair vandalism. To address this

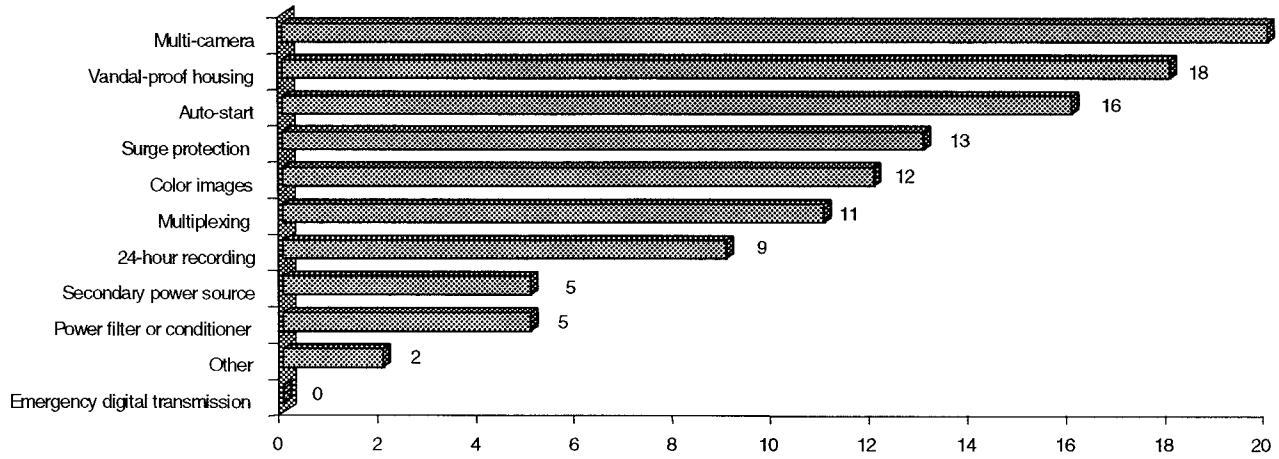


FIGURE 5 Equipment options in use.

problem and as a part of a larger claims management effort, SEPTA piloted the use of 35mm lens-shutter cameras on six fleet vehicles (*20*).

In May 1992, the agency installed an analog, closed-circuit surveillance system using VHS media, time-lapse VCRs, and monochrome video cameras. The cameras operated on 12-V DC power, were activated automatically by starting the bus, and remained in constant use during vehicle operation. The VCRs were housed under-floor in one-eighth-inch-thick stainless-steel enclosures and outfitted with damping materials and heating elements to avoid moisture and extreme cold (*16*).

Equipping each bus with these analog systems cost approximately $2,500, less than half the cost of the average claim at that time, which was approximately $5,500. Vehicles were outfitted with a CCTV system based on historical levels of claims experienced and bus usage for school service. The program was widely publicized in television news reports in an effort to preempt claims and behavior issues (*16*).

Technical difficulties did occur in the operation of the cameras. Time and date stamps worked erratically, maintenance costs were high, and upkeep of the devices was labor-intensive. Tapes had to be changed regularly to ensure the visual quality of recorded images. VCRs required frequent service and cleaning. Nevertheless, during its first year of use, passenger claims were substantially reduced, and, subsequently, cameras were installed more widely on SEPTA vehicles, with the following objectives (*16*):

- Assuring consistent and long-term system reliability with low maintenance,
- Obtaining picture quality coverage sufficient to adjudicate claims and prosecute crimes,
- Providing frame frequency sufficient to distinguish actions such as falls,
- Allowing for continuous recording for a period after vehicle shutdown,
- Guaranteeing accurate time and date stamping of the image, and
- Protecting the integrity of the reported image throughout the litigation process.

Because of the harsh operating environment on vehicles (extreme temperature ranges combined with moisture and vibration), and after evaluating several test installations, SEPTA personnel felt that on-board VHS taping systems of any type would lead to unacceptable maintenance requirements and downtime. Digital technology was implemented initially on four vehicles in January 1995, with removable, shock-resistant hard disk drives used to store data. It cost SEPTA approximately $4,850 to equip these vehicles with the digital devices (*21*).

Claim levels fell significantly after the installation of these recorders. SEPTA's annual payout for claims was reduced approximately $15 million per year when compared to 1991 data. According to the agency, a dramatic and sustained reduction in incidents of vandalism was achieved by using the CCTV system on those routes primarily used to transport students to and from school. Agency representatives reported that the behavior of juveniles was affected significantly when passengers were aware they were being recorded. Passengers' responses to the system were overwhelmingly positive (*22*). In surveys of passengers and vehicle operators during this time, the surveillance system received 90 to 94 percent favorable responses. [See Appendix E and Appendix F for surveys used to assess responses to surveillance (*20*).]

It should be noted that during this same time period SEPTA implemented a comprehensive claims reduction program that included video surveillance as one part. The extent of the impact of video surveillance in isolation is unknown, but is thought by SEPTA management to be significant, as shown by the agency's increasing investment in the technology.

Chicago, Illinois

Chicago Transit Authority (CTA) surveillance of buses

- Installation summary—$3.1 million video surveillance program involving installation of cameras on 322 city buses.
- Date installed—December 1998.
- Hours of surveillance—Interior of bus is recorded while engine is running.
- Type of surveillance—After-the-fact review of videotapes.
- Reasons for use—Designed to curb crime, graffiti, and window etching on buses.
- Results—Has resulted in a limited number of arrests.

At the CTA, video surveillance was installed on 322 of the city's buses in order to curb behavioral problems. In 1998, the total cost of this installation was $3.1 million. According to survey data, CTA uses a digital event recorder-type system that is widely employed by other agencies [e.g., SEPTA, Bi-State (St. Louis, Missouri), and Miami Valley Regional Transit (Dayton, Ohio)] This system captures and records preset video, audio, and sensor data. All information is stored on removable shock-resistant disk storage media, recorded in a secure file format with digital encryption for authentication purposes, to prevent alteration or tampering and unauthorized access.

A multiple camera configuration is used to ensure complete coverage of the vehicle's interior. The digital recorder acquires data from cameras and preselected sensor parameters as soon as the ignition is turned on and continues in this mode until the ignition is turned off.

The buses selected for system installation were those carrying large numbers of juveniles. Time- and date-stamped videotape is used to address issues of crime on buses, particularly in coordination with local school systems. For example, in a 1999 incident of vandalism, CTA officials used time and date stamps to determine which school system was boarding the bus at the time of the incident. The video was brought to the appropriate school system in order to identify those responsible (*23*). Based on the CTA survey results, the surveillance system is thought to be of average utility (rating a four out of a possible seven) overall. It is felt to be extremely effective, however, at making criminal convictions (receiving the highest score, rating a one out of a possible seven).

The agency plans to install the cameras in 140 additional buses in the near future and is considering their use on railcars as well.

Ann Arbor, Michigan

Ann Arbor Transportation Authority (AATA) Advanced Operating System

- Installation summary—Digital surveillance system on city buses is part of a larger component of the agencies' integrated Advanced Operating System. Ninety percent of the funding for the $2 million system comes from federal and state grants. AATA also has a substantial and steady base of funding from the city of Ann Arbor, due to allocations that have been built into the city charter since 1969.
- Date installed—1997.
- Type of surveillance—Recording for video playback.
- Reasons for use—Primarily concerns about the harmful effect of misbehavior on ridership levels.
- Results—Popular support among passengers and operators in terms of improving perceptions of security.

The AATA provides more than four million trips per year, with 59 buses, 27 bus routes, and paratransit service, running 24 hours a day, 7 days a week (*2*). In February 1997, AATA began a program to implement one of the most advanced integrated surveillance systems in the country.

The surveillance installation is part of a larger digital-based system operating on AATA vehicles: the Advanced Operating System (AOS). The AOS is an integrated, multisystem program that manages information-based processes, including routing, communications, passenger information, and video and audio surveillance. To support this surveillance function, the AOS includes features such as a geographic information system, advanced radio communications for data and voice transmission, automatic vehicle location, vehicle component monitoring, and on-board emergency alert system (*24*).

Initially, certain new vehicle models were equipped with three-camera video surveillance systems that record videotape for playback. Other models were outfitted with two-camera digital systems with computer-based playback. (Results of tests were more successful on systems that were specifically designed for an industrial application rather than on a standard VCR setup. Industrial systems, as opposed to those intended for home use, are more rugged and are designed to better withstand vibration and fluctuations in temperature.)

Passengers have been highly supportive of the technology. Signage indicating the presence of video and audio surveillance was met with an overwhelmingly positive response from the riding public, with few complaints relative to the number of passengers approving of the equipment installation. In addition to their safety benefits, the surveillance systems have also led to dramatically improved vehicle cleanliness.

Operators were initially hesitant about surveillance installations that captured their actions on videotape. The primary use of the cameras is not to monitor driver actions, and cameras generally are not positioned specifically to view driver activity. As the intent of the system became clearer during use, most operators became more accepting. Additional benefits to operators became clear with continued use of the system. The front camera on each vehicle, which is positioned above the driver's head, is also equipped with a microphone, which has helped managers adjudicate fare disputes between drivers and passengers by allowing them to see and hear exactly what has happened.

St. Louis, Missouri

Bi-State Development Agency Light Rail Surveillance

- Installation summary—Test installations of both analog and digital systems.
- Hours of surveillance—During operation of vehicles.
- Type of surveillance—Storage of video for playback; records, however, are not archived.
- Reasons for use—Deterrent to disruptive behavior.
- Results—Successful at reducing complaints and problem behaviors.

The Bi-State Development Agency in St. Louis, Missouri, has performed a number of test installations of both analog and digital CCTV systems. A digital event recorder system is currently in use. The system uses two color cameras to monitor the vehicle interior, with one in the front and one in the rear of the vehicle.

At present, recorders are in place on less than 25 percent of the fleet. This choice was made for several reasons, including available funds for equipment purchase (each vehicle installation costs approximately $8,000). Also, the agency favors an approach of selecting new vehicles for surveillance equipment installation and expressly cited retrofits as problematic. All new buses ordered by Bi-State have the systems installed as an option.

The surveillance systems have been installed primarily to curb disruptive behavior on both buses and the city's light rail system. As in many communities, disruptive behavior is the primary difficulty on those routes used by juveniles. By coordinating with school systems and providing videotapes of problem activities to school officials, youths responsible for breaking system rules can be identified and subsequently disciplined through the school system (*15*).

Bi-State has experienced success in curtailing such behavior and reducing complaints from drivers and passengers regarding the student riders during the times when the test installations were in place. In addition, according to survey results, measurable increases in rider and operator perceptions of security have been experienced since the cameras were installed. Agency representatives commented on this positive perception among operators by offering that the presence of surveillance equipment "sends a message to employees that we care for their safety." According to survey results, Bi-State representatives would recommend such a system to other agencies.

Milwaukee, Wisconsin

Milwaukee County Transit System (MCTS) Digital Bus Surveillance

- Installation summary—Installation of digital cameras on 176 MCTS buses (less than one-third of the fleet of approximately 550).
- Hours of surveillance—Activated upon vehicle starting.
- Type of surveillance—Recording for playback.
- Reasons for use—Improvement of customer perceptions and deterrent effect.
- Results—Maintenance and lack of system reliability are issues. Operator perceptions of security have improved.

The MCTS has installed 176 digital bus camera systems, representing approximately one-third of the agency's entire fleet. Newer vehicles were selected as candidates for equipment installation. Outfitting each bus cost approximately $7,000, which is similar to what other agencies reported spending on digital, multi-camera setups.

However, MCTS personnel note that the systems have proven to be expensive to maintain and are unreliable, that replacement parts are difficult to acquire, and that the vendor has been unable to address warranty and service agreement problems in a timely manner. As a result, the agency faces chronic problems with out-of-service cameras, although, according to survey results, *vehicle* availability is generally not affected.

The agency, despite issues with the installation, has recommended that other similar systems install surveillance equipment to address public perceptions of safety on board transit vehicles and as a deterrent to criminal behavior. The agency has also used surveillance to disprove

fraudulent claims made against MCTS and considers the system, in general, to be an effective tool for this purpose.

Portland, Oregon

Portland (Oregon) Tri-County Metropolitan Transit District, Rail and Bus

- Installation summary—Rail and bus installation, both digital and analog versions. Later equipment installations are capable of recording in color.
- Date installed—Initial installation in 1987.
- Type of surveillance—Recording for playback.
- Reasons for use—Primarily vandalism.
- Results—Success with analog recording and implementation on bus. Expansion to digital system on bus and to surveillance of rail planned.

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met), operating in Portland, has used surveillance technology for almost 15 years. In 1987, Tri-Met successfully piloted analog CCTV cameras on three of its buses. In the mid-1990s, the agency implemented a broader installation, equipping 40 buses, those operating along routes with more criminal activity, with three analog cameras each (*12*).

More recently, Tri-Met has installed both analog and digital surveillance technologies on vehicles from its bus and rail fleet. Currently, 65 of the system's 660 buses feature three digital cameras each. Also, Tri-Met has budgeted $1.2 million for a CCTV system and cameras for its 72 light rail cars. In addition to serving as a deterrent and providing potential evidence in the event of criminal proceedings, CCTV cameras also provide the agency with strong evidence in tort cases involving passenger injury claims (*12*).

Improvements have been experienced in riders' perception of system security. Reduction in vandalism on vehicles with surveillance systems has been significant.

CHAPTER FOUR

BENEFITS OF SURVEILLANCE TECHNOLOGY

All but one of the survey respondents that use surveillance reported that they would recommend an on-board surveillance system to other agencies. This chapter explores the benefits of this technology and the reasons transit agencies find value in such systems.

Surveillance systems have been installed in the transit environment for a number of reasons: to improve passenger and employee safety, reduce fraudulent injury claims, mitigate accident and liability claims, and enhance overall security. Specifically, the following applications were cited during the literature search, questionnaire, and follow-up phases and are further detailed in this chapter:

- Crime prevention and response
- Risk management
- Legal evidence
- Response to events in progress
- Customer service
- Employee security and other employee-related issues

CRIME PREVENTION AND RESPONSE

As mentioned earlier, several transit agencies have incorporated the CPTED strategies into the design of their systems, making use of its four central tenets: territoriality, natural surveillance, activity support, and access control. Employment of surveillance equipment in the transit environment builds on the concept of natural surveillance, which holds that criminals do not wish to be observed. The technique makes use of equipment, as well as activities and people, in ways that maximize clear lines of sight and allows for easy observation of passengers in order to discourage crime (*25*).

Transit agencies typically install surveillance systems with the goal of *reducing incidents of crime and responding to those that do occur.* In the questionnaire, agencies were asked to rate the overall effectiveness of surveillance systems at reducing crime. The 20 agencies responding to this question feel their surveillance systems perform this function slightly better than average, yielding a 3.4 rating on a scale of 1 to 7 (with 1 being most effective and 7 being least effective) (Figure 6). Ten of 19 respondents reported a measurable reduction in the number of assaults experienced at their agencies. The presence of cameras also has an effect on vandals, with 13 of 20 respondents reporting a measurable reduction in vandalism.

Beyond crime prevention, surveillance records can be useful in obtaining convictions of those who commit crimes on vehicles, and especially in addressing public disorder issues. Common applications include recording and prosecuting those who commit vandalism, engage in minor altercations or disorderly conduct, or repeatedly break system rules. The 15 transit agencies responding rated their systems at a 3.4 on average (on a scale of 1 to 7) in terms of effectiveness at making criminal convictions, somewhat better than average (with one being "most effective"). In addition, the presence of agency videotapes has facilitated plea bargains or caused individuals to drop groundless lawsuits.

Studies have shown that crimes, and certainly serious crimes, occur no more frequently—and often less frequently—within transit systems than in surrounding neighborhoods, and that transit crime generally parallels that of the larger community (*26*). Therefore, transit agencies often install surveillance systems with the goal of *mitigating passenger fear* of using the system. Ten of 17 agencies with on-board surveillance surveyed reported a measurable increase in rider perceptions of security. Twelve of 20 agencies surveyed with on-board surveillance reported a measurable increase in operator perceptions of security. Efforts at mitigation of passenger perception concerns and instances of criminal activity often are taken with the end goal of increasing transit ridership. As reported by Richards and Hoel, "perceived security, not actual security, is what influences ridership and transit use patterns" (*27*).

RISK MANAGEMENT

Verification of insurance claims resulting from (alleged) accidents in an attempt to reduce fraud has become a serious issue for transit agencies. Ten of 22 responding agencies have used surveillance recordings to disprove claims made against their systems. Industry experts at several agencies assert that a single fraudulent claim can yield $5,000 or $10,000 (the average value of a claim at SEPTA in 1991 was $5,500) (*16*). Furthermore, it is not uncommon for persons to intentionally cause accidents with transit vehicles to yield a basis for making these claims. Therefore, a number of surveillance systems have been installed primarily to address insurance claims, which at some agencies are believed to be predominantly fraudulent.

During its implementation of on-board surveillance in the mid-1990s, SEPTA experienced a claims reduction of

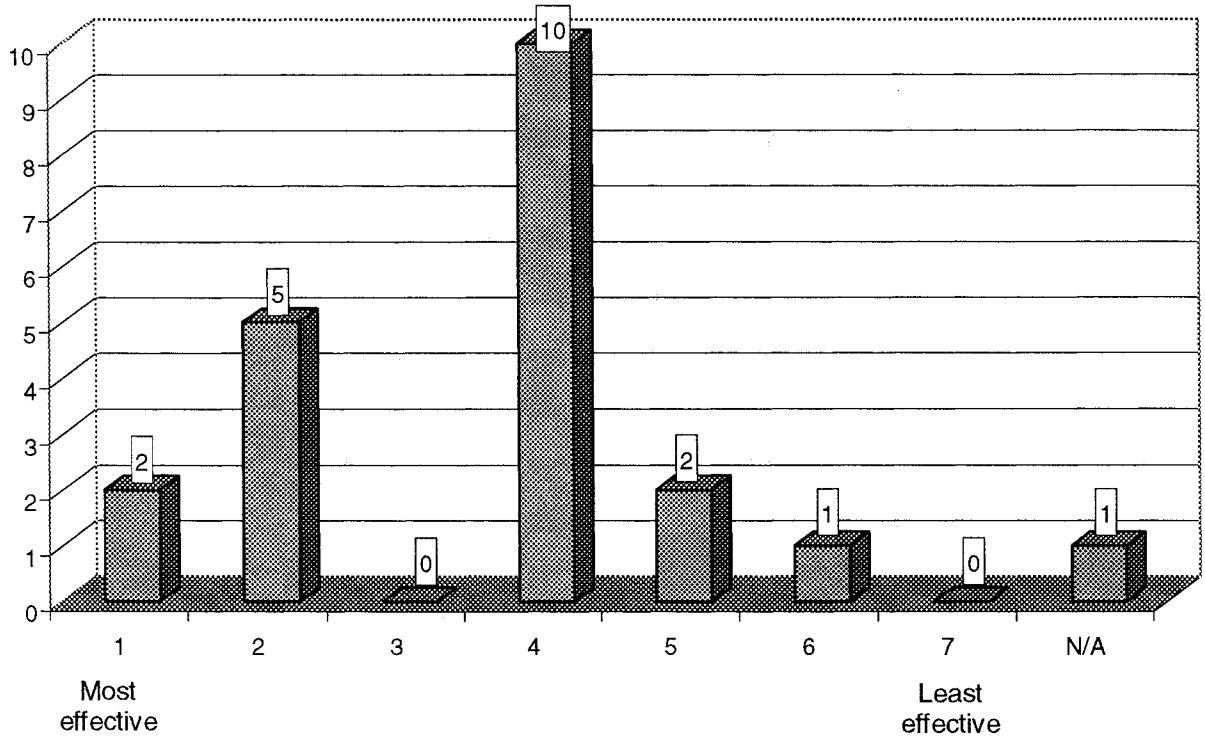


FIGURE 6 Effectiveness of surveillance system at reducing crime.

32 percent. Although it is difficult to project the effect that the use of surveillance will have on fraudulent claims at other agencies with other claims issues, for SEPTA estimates of annual claims-related savings were placed at $2.2 million. This reduction was not entirely due to the installation of cameras, since SEPTA used the surveillance program as one part of a larger program aimed at targeting fraud. Installation of each digital system cost $4,850 and each analog system cost approximately $2,000 (*16*).

LEGAL EVIDENCE

Many agencies install surveillance systems on vehicles to provide continuous, random, or emergency monitoring of vehicles for use as evidence in legal proceedings. These recordings can either aid in making criminal convictions or support risk management efforts in protecting agencies against false or exaggerated claims. Ten of 19 agencies responding to the questionnaire have used recordings from their surveillance systems as evidence in court.

In addition to video images, some digital systems have the capability of being integrated with sensors tied to brake lines, warning lights, turn signals, doors, accelerators, and other pieces of equipment to monitor and record use. These records, which can contain date and time information as well as vehicle speed, can be used to re-create the circumstances surrounding an accident, often supplying necessary supporting evidence for use in court. Strategies and difficulties related to records retention and chain of possession are described in the next chapter.

RESPONSE TO EVENTS IN PROGRESS

Most systems equip their vehicles with emergency call buttons to alert central control in the event of an accident or incident. These call buttons can be either driver-activated or automatic. Automated systems can be configured so that a sudden jolt or heavy impact causes activation and, in some cases, automatic transmission of audio and video information to central control. Emergency audio or video signal transmission can be made to a police, security, or dispatch center to initiate emergency response or to ensure that an event is recorded.

Furthermore, in order to provide incident management support, transit agencies may choose to implement systems allowing remote access of audio and video information captured on the vehicle to monitor relevant activity, as with MBTA's radio frequency transmission system discussed earlier. Especially in extremely serious crime situations, status information from on board the vehicle can be helpful for police and other emergency personnel in resolving incidents.

CUSTOMER SERVICE

Though typically not installed primarily to address customer service needs, transit agencies have begun to use limited surveillance systems in this role. Surveillance systems can provide audio monitoring or visibility of passengers on vehicles. Audio, and in some cases video, signals can be transmitted to a dispatch, security, or police center, allowing support personnel to intercede in passenger and operator disputes or to identify patrons with problems.

Fare Dispute Mediation

One application of this customer service capability is in the area of fare dispute mediation, which though not commonly used within the transit environment, remains technologically possible. Audio or video information can be used *following* or *during* a fare dispute to support an operator in resolving a situation in which a patron does not pay the required fare. Agencies such as AATA, Central Ohio Transit Authority (Columbus, Ohio), and Torrance Transit (California) reported using their systems for this purpose.

Complaint Resolution

Eight of the 20 agencies completing a related survey question reported using their on-board surveillance systems for the purpose of resolving customer complaints. Agencies with systems using this application include the Regional Transportation District of Denver and Golden Empire Transit District serving Bakersfield, California. Surveillance technology, with its recording potential, offers transit agencies the capability of proving or disproving criticisms made by passengers about system equipment or employees. Agencies were asked to rate the overall effectiveness of their surveillance system in complaint resolution, yielding an average rating of 3.6 (out of a possible 7).

EMPLOYEE SECURITY AND OTHER EMPLOYEE-RELATED ISSUES

The use of surveillance technologies to monitor the conduct of employees is a controversial application as well as a potentially valuable tool. Surveillance provides information applicable to three areas of benefit relating to transit agency employees: (1) protection of employees through monitoring, (2) risk management through observation and efforts at accident avoidance, and (3) working to resolve passenger complaints. Video captured of the interior activity of a bus is valuable in countering the threat of crime, in court prosecution, in assisting in driver training, proving fault in an accident, and as a general risk-management tool.

Employees can be the victims of serious crimes on board vehicles, as seen in Table 2. Significantly more robberies and aggravated assaults, both crimes that include force or the threat of force, occur against employees while they are on board transit vehicles than at other locations within the transit environment.

TABLE 2
CRIMES COMMITTED AGAINST TRANSIT EMPLOYEES DURING THE 1998 TRANSIT AGENCY FISCAL YEAR, BY LOCATION

Crimes Against Transit Employees	On Board Vehicle	Other Locations
Homicide	1	1
Forcible rape	2	3
Robbery	120	33
Aggravated assault	478	137
Larceny/theft	443	871
Motor vehicle theft	NA	82

Source: FTA, *1988 National Transit Database* (*6*).
Note: NA = not available.

In general, workplace violence is an issue in many environments, and video surveillance is used as a countermeasure. According to the Department of Justice's National Crime Victimization Survey, the most common type of workplace violent crime was simple assault, with an average of 1.5 million a year (*28*). The risk rate (per 1,000) for various occupations was as follows (*29*):

Police officers	306
Private security guards	218
Taxi drivers	184
Prison guards	117
Bartenders	91
Mental health professionals	80
Gas station attendants	79
Convenience, liquor store clerks	68
Mental health custodial workers	63
Junior high/middle school teachers	57
Bus drivers	**45**
Special education teachers	41
High school teachers	29
Elementary school teachers	16
College teachers	3

Factors that may increase a worker's risk for workplace assault, as identified by the National Institute for Occupational Safety and Health, include the following (*30*):

- Contact with the public;
- Exchange of money;
- Delivery of passengers, goods, or services;
- Having a mobile workplace, such as a taxicab or police cruiser;
- Working with unstable or volatile persons in health care, social services, or criminal justice settings;
- Working alone or in small numbers;
- Working late at night or during early morning hours;
- Working in high-crime areas;

- Guarding valuable property or possessions; and
- Working in community-based settings.

Most of these risk factors are either applicable to the transit environment all of the time (e.g., contact with the public) or some of the time (e.g., working in high-crime areas).

The Occupational Safety and Health Administration (OSHA) does not have a specific standard for workplace violence. However, under the Occupational Safety and Health Act of 1970, the extent of an employer's obligation to address workplace violence is governed by the General Duty Clause. Section 5(a)(1) of the OSH Act, or P.L. 91-596 (the "General Duty Clause") provides that: "Each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees" (*31*).

OSHA does offer guidelines and recommendations to help prevent and mitigate the effects of workplace violence. Among the engineering and administrative controls recommended by OSHA is the use of "video surveillance equipment and closed circuit TV" in the workplace. In addition, employee perceptions regarding a lack of security are significant. While operating a transit vehicle, employees are generally isolated and removed from observation by security personnel or other system employees. Most agencies (12 of 20 responding to this question) report a measurable increase in employee perceptions of security since the installation of their CCTV system.

Multi-camera setups used by most transit agencies are configured to provide a full view of events taking place within the vehicle, including those involving the operator, which can be useful in recording crimes against employees as well as patrons. In addition, the use of video cameras to deter crime against employees, as with passengers, is one of the reasons cited by transit agencies for installing cameras on board vehicles.

One drawback of surveillance systems among employees and labor organizations is that employee surveillance is frequently believed to be overly intrusive. Many transit agencies would rather forego the use of surveillance for employee monitoring purposes in order to encourage employee support of the overall surveillance program. SEPTA management, for example, offered that, "labor organizations should be included in the process early to dispel the notion that camera systems are designed to monitor rather than to support the operator" (*16*).

Most transit agencies use this approach in implementing surveillance technologies to allay such concerns. Nineteen of the 23 agencies responding to the question of whether they solicited input from union representatives on the subject of on-board surveillance technology answered that they had. Agencies reported that employee unions had expressed concern about several issues, including employee privacy concerns (14 agencies), employee safety (11 agencies), and employee liability (2 agencies).

In addition to security issues, records of operator–passenger interactions are potentially useful in determining training needs, designing training procedures, ensuring that safety procedures are being followed, or determining operator-based causes of accidents. For complaint resolution, data records can be used to assess the veracity of accusations against employees, to confirm whether training is adequate in a particular area, or as a substantiated basis with which to initiate disciplinary action.

Features exist on event recorders that allow for the recording of vehicle operation risk factors, including vehicle speed, acceleration, and braking patterns. In addition, the devices can monitor operator use of safety equipment such as turn signals and headlights. Finally, the activation of other vehicle equipment such as vehicle doors can be confirmed (e.g., to ensure vehicle is fully at rest when doors are opened).

CHAPTER FIVE

ISSUES WITH THE USE OF SURVEILLANCE TECHNOLOGY

This chapter addresses the three types of issues found to exist with surveillance technologies on vehicles.

- Financial,
- Legal, and
- Mechanical and procedural.

Each is discussed in detail as related to surveillance installations.

FINANCIAL ISSUES

In recent years, the price of surveillance systems has declined and it continues to fall as the technology becomes more commonplace, bringing the practice of on-board surveillance within the financial reach of more transit agencies. Surveillance systems are now offered as an option on new transit vehicles. Even with reduced costs, surveillance devices still represent a significant investment for most properties. Costs exist in the stages of equipment purchase, installation, maintenance, and management. Consequently, there is a pronounced need to ensure that expended funds are invested most cost-effectively, given the nearly universal constraints on transit funding.

Nine respondents answered the survey question regarding system installation cost. Answers ranged from $1,100 to $10,000 per vehicle, with a median cost of $6,500. Differences in configurations explain much of the price differences. The lowest priced system was installed in a small bus agency serving a rural population. This system consists of analog CCTV cameras with a VCR unit and incorporates dummy cameras to supplement functional cameras. On the high end of the scale was a system installed in a heavy rail environment in which electronic noise is a concern. This setup made use of a digital CCTV system with multiple cameras and a digital recording unit, with digital cameras and recorders. Pan-tilt-zoom cameras were employed, which could be remotely repositioned. Pan-tilt-zoom cameras are somewhat unusual in this application, with most agencies relying on fixed cameras. The signals from the cameras were transported by means of fiber optic cable.

Generally, this trend is reflected in the survey responses, with simple analog CCTV systems being the least expensive setups, and those digital CCTV systems with complicated configurations being the most expensive. Medium-priced systems tend to be digital event recorders. The single most common type of installation is a digital event recorder, with six agencies making use of the same make of recorder. Six agencies using this equipment supplied prices for their systems, which were consistently between $5,000 and $7,000 per vehicle, depending primarily on when the system was installed.

Several sources of funding exist to help agencies pay for surveillance systems, including FTA grant programs, state grant programs, local funding, and internal funds. Federal funding from the FTA was the most common source of capital for purchasing surveillance systems. In addition, slightly less than one-third of the agencies responding to this survey question used various combinations of these sources to cover installation costs (Figure 7).

LEGAL ISSUES

General Legal Challenges

The legal implications of surveillance on transit vehicles are a significant issue, judging from the responses of surveyed agencies. Federal and local laws define the rights of entities to observe activity on a vehicle and, in particular, to record images from these observations that may be used later as evidence in court or for other purposes. Conversely, the Fourth Amendment to the U.S. Constitution states that "the right of the people to be secure in their persons, houses, papers and effects, against unreasonable searches and seizures shall not be violated . . ." and is most often cited in opposition to surveillance programs (*32*).

As this area of law is relatively new and because precedent and, therefore, limitations are predominantly identified on a state-by-state basis, neither clarity nor uniformity is present with regard to the issue in the industry. States, through specific legislation or through precedent set in the judicial system, have established bounds that are often not clearly defined regarding the legality of recording audio- and video-based information for government use from a public space. Rulings on evidence by judges, therefore, are integral to the use of surveillance.

A number of challenges have been brought forth questioning the right of the police or another public agency to use surveillance without a warrant. Several states, however, through court decisions or findings of appeals courts,

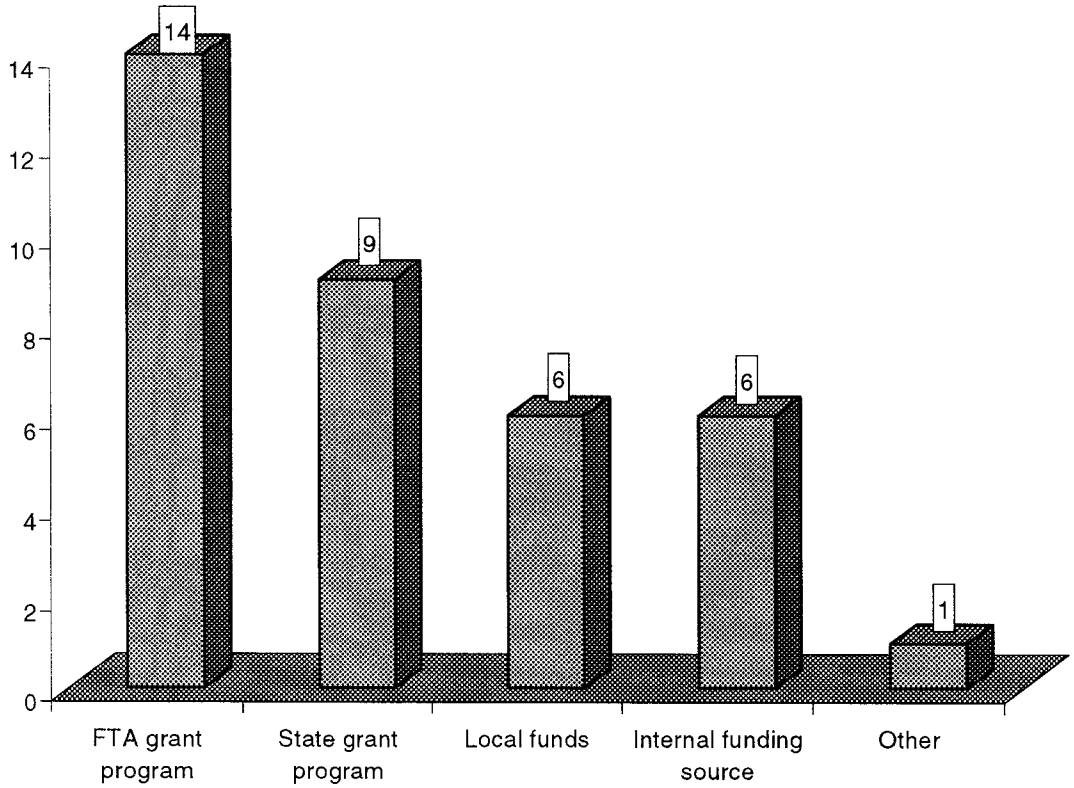


FIGURE 7 Source of funds for surveillance systems.

have upheld the rights of police or other entities to record certain classes of events occurring in a "public space." For example, a Maryland appeals court found that video surveillance in public areas *is* compatible with Fourth Amendment requirements as well as Title III of the Omnibus Crime Control and Safe Streets Act (OCCSSA) (*33*). In *McCray v. State of Maryland* (*34*), as a part of an investigation, police conducted a warrantless video surveillance, videotaping an individual crossing a public street. The court held that such surveillance was allowable because the video surveillance of the defendant took place only while the individual was in full public view. The court stated that a person does not have a *reasonable expectation of privacy* when he is walking along public sidewalks, streets, or parking lots, or in a similar location in full public view (*35*). The concept of expectation of privacy in public areas is an important one that has been applied in a number of similar cases.

The acceptance of *digital* recordings in a court of law has yet to be proven in the United States. Other countries, however, including the United Kingdom, have tested and in some cases approved or recommended types or methods for digital data authentication to ensure acceptance by the court system. These recommendations include:

- *Use of original recordings*—Original recordings, as opposed to duplicates, provide far stronger evidence for use in court.
- *Use of a recording format in which stored information cannot be altered or rewritten*—The "write once read many" protocol (WORM) has become the standard for ensuring that modifications cannot be made, while allowing a recording to be viewed as many times as is necessary.
- *Use of a check sum*—Check sums are methods by which the system records a number somewhere in the recorder's program. Upon reviewing a recording, this number is matched for consistency with the system check sum. If unequal, an alarm or visual indication notifies the reviewer that changes have occurred.
- *Use of digital signatures*—Time and date stamps, clocked at rates preferably as high as one one-hundredth of a second, enhance the credibility of video surveillance records for use in court (*32*).

In August 1998, an American Bar Association Task Force on Technology and Law Enforcement attempted to develop standards to guide the use of CCTV usage in its "Standards for Criminal Justice on Electronic Surveillance." The Association's House of Delegates adopted these standards (*32*).

Because it is a new technology, fewer courts have considered cases involving mobile digital event recorders. Analogous situations do exist, however, in the law pertaining to other recorded events that may give rise to

litigation or prosecution. The test applied by courts in determining admissibility of surveillance recording generally includes the following elements:

- Showing that the device is capable of recording what a witness to the scene saw or heard had a witness been present at the scene of the event.
- Proof that the device, a process, or mechanism was competent.
- Establishing the authenticity and correctness of the recording (chain of possession safeguarded).
- Showing that no changes, additions, or deletions have been made.
- Demonstration of the manner in which the recording or video is preserved.
- For criminal cases in which law enforcement officials are involved, showing that any statements made or actions taken on the recording or tape were made voluntarily without inducement.

As a part of the OCCSSA, Congress enacted a prohibition of wire interception and intercept of oral communications and provided a right of action to violations thereof. This Act provides restrictions on interception and disclosure. Furthermore, it enforces civil and criminal penalties for illegal eavesdropping, establishes eavesdropping as a violation of the right of privacy, and limits admissibility into criminal prosecution of evidence secured by mechanical or electronic eavesdropping devices. Finally, the Act provided a basis for state statutes, building on the federal statute, which can be more restrictive.

This prohibition has allowed states to place more restrictions on the use of surveillance. For example, in *State v. Diaz* (*37*), New Jersey upheld the right of police to use videotape as evidence only if used apart from a sound component. New Jersey's Wiretap Act, which is modeled after Title III of the Federal OCCSSA, does not, it was decided, restrict silent television surveillance, and the legislative history of the federal legislation indicates that the exclusion was deliberate. The admissibility of videotape containing a sound component in a criminal proceeding was found to be governed by the warrant provisions of the New Jersey statute.

Agencies can make certain arguments for admitting such evidence including the following:

- That recordings were made through a business necessity, which is generally difficult to prove for an entity such as a transit agency
- That consent was given by one party, which is sufficient in many states for recordings. In some states, consent of both parties is required. Signs describing that surveillance is being performed may be adequate to fulfill this requirement.
- That there is no reasonable anticipation of privacy in such a situation, such as recording performed on a public street (*38*).

Court cases *have* been brought regarding surveillance on vehicles. In 1995, a plaintiff sued SEPTA for injuries allegedly sustained during a sudden stop. SEPTA won this case, but upon hearing of the fact that surveillance had been performed, the plaintiff sued for emotional distress as a result of SEPTA's use of video surveillance to monitor the plaintiff's actions. The plaintiff filed a state court complaint and subsequently asserted federal claims, based on violations of Pennsylvania state statutes and numerous state law theories involving intentional torts, a trespass, and fraud and deceit.

The claimant attempted to show that SEPTA maintained a policy, practice, and custom of engaging in "intentionally unsettling and intrusive surveillance" of injured claimants to disparage claims and punish those who bring claims against the agency. By engaging in this conduct, the complaint contended that SEPTA violated the plaintiff's constitutional rights, including rights to personal security, rights to personal liberty, and substantive due process to privacy as guaranteed by the First, Forth, Ninth, Tenth, and Fourteenth amendments to the U.S. Constitution.

As an agency of the Commonwealth of Pennsylvania, SEPTA is afforded all sovereign immunity protection provided by Pennsylvania statutes (*39*) whereby a Commonwealth party cannot be held liable for damages arising out of intentional torts. Sovereign immunity defense precluded all claims for intentional torts based on negligent infliction of emotional distress in punitive damage claims. The finding of this case was that surveillance was not intrusive.

An important aspect of protecting the use of recorded information as evidence is to develop a clear program for handling and archiving data following predetermined rules related to evidentiary chain of custody. A form used by SEPTA for this purpose is included as Appendix G.

Advertising Surveillance

Transit agencies performing surveillance have encountered legal concerns in another area in particular—signs accompanying surveillance equipment; that is, that the gathering and recording of information via surveillance systems be performed precisely in the manner that the surveillance is understood by the public and, above all, that the surveillance is "advertised" to the public. As a result, if signs are presented to assert that surveillance is being used, this constitutes a legal obligation by the transit agency to the public in some instances to perform such surveillance. Again, the existence and nature of this obligation differs from state to state.

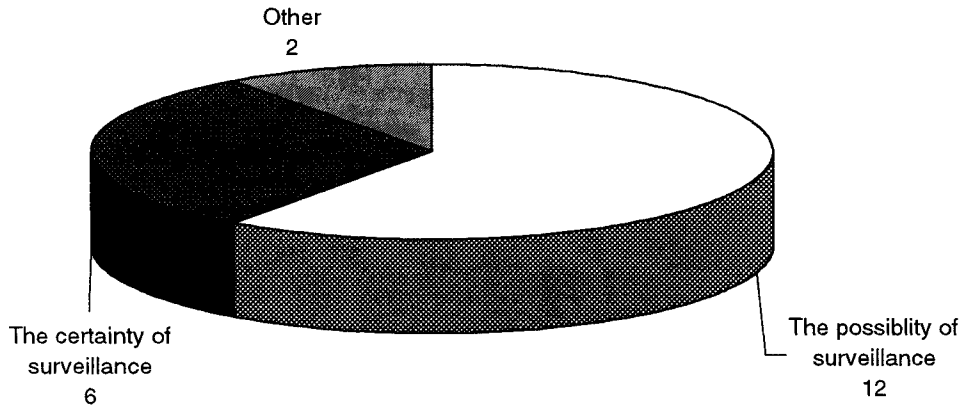


FIGURE 8 Information conveyed by signage.

Transit agencies surveyed for this study and those described in the literature have documented the actual or perceived value of a deterrent effect resulting from the installation of surveillance equipment on vehicles. The presence of such devices, no matter what physical evidence they may generate, is sometimes described as their greatest advantage in addressing crime. Among questionnaire respondents, San Francisco MUNI, Milwaukee County Transit System, and Bi-State all cited crime deterrence as a reason they would recommend a surveillance system to other agencies. Because of this effect, agencies often wish to publicize the use or existence of monitoring equipment to encourage this deterrent effect.

Agencies taking part in the study seemed to use care in devising signage to achieve this goal, because of the legal implications stemming from any assertions made by the transit agency in the signage. Twenty-three of the 26 respondents replied that their agency used or planned to use such signage; however, the message conveyed on signage is typically restrained and in most cases indicates only the possibility of surveillance (Figure 8).

The wording on these signs is included for reference in Table 3. For further information on legal issues related to posting such signs, readers are encouraged to refer to ordinances and case law applicable to their localities.

In some situations, recording devices on vehicles are only activated in specific situations, such as when the operator depresses an emergency call button. Signs stating that video recording is being performed on the vehicle have proven troublesome to some transit agencies, because one potential legal interpretation of such a statement is that

TABLE 3
SIGNAGE WORDING

Agency	Signage Wording
AC Transit District, Oakland, Calif.	For your protection, 24-hour video surveillance system is operating on this coach
Bay Area Rapid Transit District	Warning, your picture may be recorded on this vehicle
Santa Monica's Big Blue Bus, Santa Monica, Calif.	This vehicle is equipped with cameras
Chicago Transit Authority	Attention. Surveillance cameras may be on board
Houston Metro	Closed-circuit video cameras monitor these premises
San Francisco MUNI	Warning: your picture and voice may be recorded on this vehicle
Regional Transportation District, Denver, Colo.	Roaming security—because we care for your safety, RTD provides uniformed and undercover police as well as video surveillance to monitor passenger activity on buses
SunLine Transit Agency, Thousand Palms, Calif.	Warning! This bus may be equipped with video recording devices which may or may not record your activities while a passenger on this bus. Any recordings made may be used by SunLine Transit Agency and/or turned over to the appropriate authorities [Sign is posted in both English and Spanish.]
Island Transit, Coupeville, Wash.	For all our protection, transit vehicles are equipped with audio and video cameras . . . So smile . . .
King County Metro Transit, Seattle, Wash.	For our customer's safety and security, activities on board this bus may be visually and audibly recorded
Miami Valley RTA, Dayton, Ohio	For your safety this bus is being monitored by an on-board security camera
Valley Transit, Appleton, Wisc.	This area is being monitored for your protection
VIA Metropolitan Transit, San Antonio, Tex.	Surveillance camera on bus
Antelope Valley Transit Authority, Lancaster, Calif.	For your safety and comfort, this bus is outfitted with security cameras

surveillance is being performed at all times on these vehicles. According to a representative of Portland Tri-Met, transit agencies should "use careful wording in signage. Wording that implies the cameras are there 'for your safety and security,' for example, may open an agency up to liability . . . rather, it is better for signs to simply inform the public of the presence of the cameras" (*12*).

The above cases (those in which the transit agency is asserting that it is performing certain surveillance activities) are, perhaps, most legally clear. In addition, legal issues have arisen, in which the transit agency, by performing surveillance or appearing to perform surveillance has been found to have established an "agreement" with the public to carry out this responsibility. That is, by implementing functional or nonfunctional surveillance equipment, a transit agency is, in some sense, asserting that it is or will be performing surveillance and is required to carry out this function.

In some cases, by installing camera housings that may or may not contain surveillance equipment, agencies have experienced legal consequences if this was not, in fact, the case. When on-board or other surveillance constituted an emerging technology, some agencies, recognizing the deterrent effect of maintaining or merely appearing to maintain video surveillance, did, in fact, install "dummy" cameras or housings to achieve this effect, avoiding the expense of purchasing cameras to equip an entire fleet. Because of the legal implications (i.e., the threat of lawsuits), this practice is now far less common. Concerns may even arise when cameras are removed from the vehicle without the removal of housings, mountings, or other equipment. The use of dummy cameras is becoming less prevalent, with only one agency in the survey responding that such cameras were used on its buses.

MECHANICAL AND PROCEDURAL ISSUES

Maintenance of Equipment

The issue most commonly cited by questionnaire respondents was that of system maintenance, with 9 of the 13 respondents to this question answering that maintenance is "the most significant weakness of the system" (Figure 9). Note that several of the agencies surveyed offered multiple responses to this question. Also note that agency needs and perspectives are different. The agency with the least expensive setup was the only agency to cite "cost" as the most serious system weakness.

The ongoing maintenance and repair of surveillance equipment constitutes a significant cost in implementing such a program. Costs include: routine maintenance of cameras and, in particular, videocassette recording equipment;

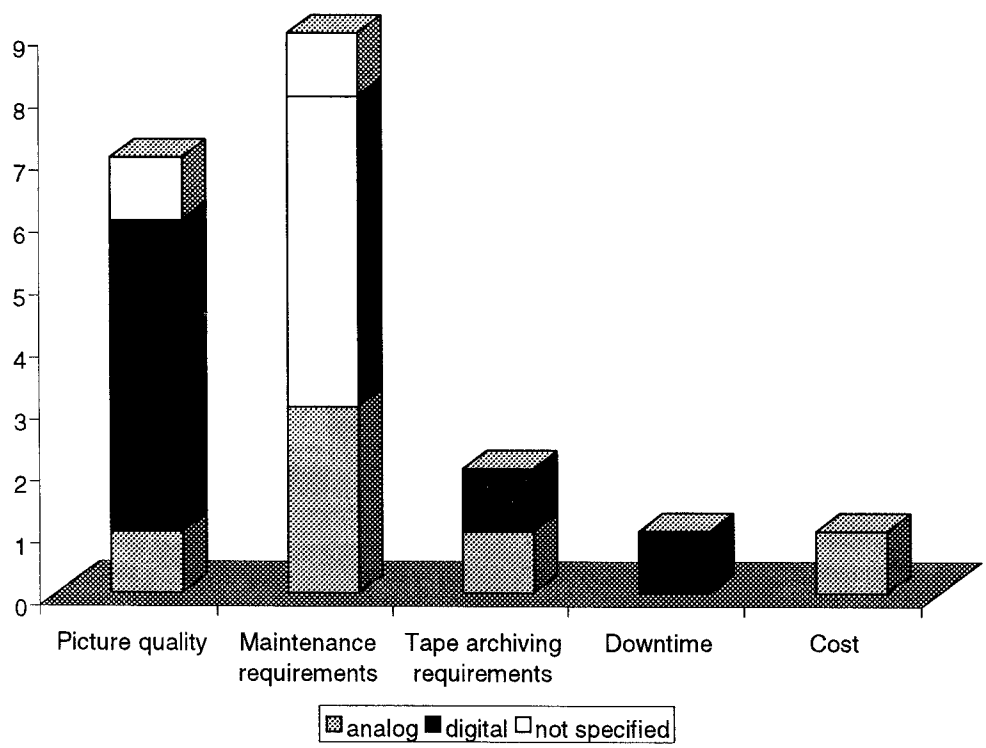


FIGURE 9 Most significant weaknesses of surveillance system.

vehicle or equipment downtime as a result of the need to repair surveillance systems; parts and labor, which often must be acquired from the equipment manufacturer or systems integrator directly; training of maintenance staff; training of operators with regard to the use of surveillance equipment; archival, storage, and retrieval costs of videotapes or other surveillance records; and development of procedures pertinent to systems.

Discussions with agency representatives revealed that agencies most often encounter difficulties with respect to procedures, roles, and responsibilities at the time systems are initially installed. As with any technology, human interfaces and procedures must be established in order to obtain optimal benefit from the system. In addition, agencies must assign personnel (either operations, maintenance, police, or security) to perform all requisite tasks.

Among the trade-offs with the less expensive initial costs of analog surveillance systems is added maintenance. Not only do video recorders require regular servicing, but also tapes must be checked. Archiving of tapes is another significant issue. As discussed earlier, various options exist for videotape recording times. Some agencies, for example, catalog tapes and maintain a 30-day assortment, changing the tape every day before the bus goes out. Other agencies allow each tape to automatically rewind and begin recording over itself, pulling tapes only when a known incident occurs. Tapes must be discarded regularly to ensure adequate picture quality, with replacement performed at any of a number of manufacturer-recommended intervals: 1,000 hours, 20 days, 30 days, or other milestones. This replacement requires further, scheduled effort on the part of the maintenance staff. Furthermore, the quality of archived tapes degrades over time.

Digital systems require less maintenance than do analog systems. Although analog systems are used far more universally in the security industry as a whole, as discussed earlier, the clear majority of agencies responding to the survey reported using a digital surveillance system. Maintenance requirements generated by analog systems in such a harsh environment are a significant contributor to this disparity. Digital systems do have maintenance needs, however. DAT or DSS tape maintenance costs increase because of the number of moving parts, compared with disc drives that have one moving part.

Consumer product testing firms have found that all tapes record the full bandwidth of their respective formats (e.g., VHS, 8mm, S-VHS), and that there does not seem to be a difference even between regular grade and "high-grade" tapes. One defect of videotape is "dropout," in which the signal is temporarily lost, requiring resynchronization during replay. The frequency of these dropouts determines the relative quality of videotapes. Although the average viewer would not notice most dropouts, for applications such as transit surveillance, dropout frequency may jeopardize the utility of videotapes. In general, it may be better to buy brand-name tapes to help ensure that quality-manufacturing standards have been applied (*9*).

In reading tapes, the environment also plays a role. The heads that read a tape do not make contact, but force a film of air between the heads and the tape due to friction and high rotation speeds. Moisture particles can be larger than the gap between the rotor and the tape, causing drag and improper operation (*9*).

The most common maintenance task for VCRs is head cleaning, although some equipment is available with self-cleaning heads. The requirements for cleaning heads are somewhat ill-defined. Professional cleaning is most effective, and involves disassembling the unit. In addition, head cleaning tapes are available, which consist of an abrasive material manufactured into a standard-sized cassette and used in conjunction with a cleaning fluid. Because of their abrasive effect, certain manufacturers warn against damage caused by their use, and they are not universally effective (*9*).

In addition, several agencies cited the difficulty of needing to reset the time and date stamp information regularly and to account for daylight saving time. Users of both digital and analog equipment noted this maintenance issue.

Durability

The durability of systems is a significant concern, as well. The application of surveillance technology to transit vehicles has been especially difficult with respect to three factors: vibration, temperature, and humidity concerns.

According to the literature and questionnaire responses, VCRs are the surveillance system components most vulnerable to vibration. As confirmed by participating agencies, as well as information obtained in the literature review, many problems relating to analog systems stem from an inability to keep the VCRs operating reliably. Some agencies have equipped their vehicles with standard recording devices, not designed for a transit or commercial application, typically with less favorable results. Equipment designed for on-board applications is normally insulated from shock and vibration, absorbing up to 95 percent of the vibrations.

Extremes in heat, cold, humidity, and dust also create problems for equipment. Systems are available that make use of environmentally controlled housings using heating elements and dehumidifying equipment. In addition,

surveillance systems must be protected from other environmental effects, such as electrical surge. Surges occur randomly and frequently on transit buses and can be hundreds of volts in magnitude.

Archival

Surveillance video must often be stored for extended periods of time to meet transit agency legal or internal requirements. Retention of video records must meet the needs for which the system is designed. If a surveillance system is to be used for civil claims, for example, claims typically may not be filed for up to 1 year after an accident or other relevant event. One questionnaire respondent stated that (in this case, digital) video records at his agency are kept indefinitely. Other agencies having an archival program, according to the questionnaire, retain video records for a few days or until a case in question is resolved. Information is stored on various media (for example, VHS tape or 8mm tapes, which occupy significant amounts of physical space. Because 10 of 22 of those responding to the questionnaire reported that data were archived at their systems, storage and archival of data is a significant issue given that the process can be cumbersome, especially when management of surveillance data fall under rules of evidence.

The use of hard drives to store information, which then may be downloaded to a computer in the maintenance facility as part of routine maintenance, simplifies the archival process. Since digital information tends to be more easily transmitted, such a system offers the capability of allowing the user to transfer downloaded information from the maintenance facility to a central storage facility without the need for large quantities of physical space for tapes. On the other hand, digital information has archival requirements as well. Although information from hard drives is only saved on a case-by-case basis and is otherwise overwritten, adequate hard drives must be allotted for the information. Digital information also must be safeguarded while in transit from the vehicle to the maintenance facility to the ultimate location of its archival.

Some vendors offer data management services that facilitate secure long-term video storage. Because of the administrative complexity of storing and retrieving recorded images, some firms offer services to support this function, including building, hosting, and managing of data archives. Customers (i.e., transit agencies) can choose to upload their own data or contract an outside company to handle data collection from specific vehicles or sites. An outside firm can also provide conversion services that place audio, video, and sensor information onto storage media, including digital cartridges, videotape, and digital audiotape drives (*17*).

CHAPTER SIX

CONCLUSIONS

For a number of years, technology-assisted surveillance strategies, such as closed circuit television, have been used to support transit personnel in addressing security and safety issues. As applied for use *on board vehicles*, however, the technology is still emerging. Enhancement of system capabilities and selection is ongoing, while prices and reliability of equipment are making the technology a viable option for an increasing number of transit properties. Agencies face a greater variety of choices when making a purchasing decision on such equipment, although in many cases this equipment has not been definitively studied for measurable effectiveness.

This study assembles much of what is currently understood about this technology, through a review of relevant literature, supplemented by an agency survey and discussions with agency representatives. The result is a synthesis of types of equipment available, the distribution of equipment types throughout transit agencies at present, benefits and potential benefits associated with on-board surveillance, and issues and potential issues concerning on-board surveillance. Much of the information is necessarily anecdotal.

Reflecting generally positive attitudes towards the technology, the most common survey response was that agency representatives regretted not implementing a more widespread program of on-board surveillance or a program in which more cameras were installed to capture information. Only one agency representative responding to the questionnaire indicated that they would advise against a similar transit agency installing an on-board surveillance system.

Again, although analog systems are far more popular than digital systems in the security industry as a whole—that is, used in all security applications, in all types of facilities, and in other locations—17 of the 21 respondents used digital systems. Of the six systems that used analog surveillance, two used digital systems as well (i.e., analog systems may have been installed at an earlier date and are gradually being replaced by digital equipment). Based on the survey results, relevant literature, and discussions with agency representatives, digital systems appear to be the strong preference within the transit industry when applied to mobile surveillance applications.

Although it is difficult to project the precise effect that the use of surveillance will have on cost savings, information from one agency's management resulted in the following "lessons learned":

- Cost savings due to fraud reduction can be significant. It was estimated that the use of video cameras on routes in which fraudulent claims are a serious financial problem have contributed to an approximately 25 percent reduction of claims payouts.
- The surveillance "program must be well-publicized and be the central element in a larger campaign that focuses managerial attention on specific problem areas along routes selected such as peak loading points, high accident areas, and routes heavily used by (juveniles)."
- "Labor organizations should be included in the process early to dispel the notion that camera systems are designed to monitor rather than to support the operator."

Overall, it is clear that agencies using on-board surveillance technology find the systems useful in terms of benefits received and potential benefits offered. Responses to questions about benefits did not point to one area in which the systems were singularly effective, leading researchers to the conclusion that system effectiveness in a combination of applications (e.g., reduction of fraudulent claims, crime deterrence, perception of safety and security, and legal evidence in criminal cases) yielded a situation in which agencies felt the systems were beneficial, as a whole. Nearly all would recommend that similar agencies install surveillance systems.

Synthesis results support further study. It would be appropriate that transit agencies begin to collect data regarding the installation of such equipment in order to substantiate the general belief that surveillance is an effective technology. The following would be particularly useful:

- A compilation of crime levels experienced before and after system installation,
- Results of surveys administered to passengers and employees regarding security perceptions before and after system installation (see Appendixes F and G for examples),
- Data regarding claims levels on railcars, buses, and routes, in which on-board surveillance is in use,
- Numbers of times surveillance recordings are used for specific purposes,
- Ridership totals before and after system installation, and
- Maintenance costs including labor and materials.

These data would be particularly useful for agencies considering the use of on-board surveillance as well as for agencies that have such systems and wish to justify program expansions or updates to management.

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GLOSSARY*

Amplified light—An attribute of a camera or other video device indicating the use of a special module to amplify ambient light before it gets to the pickup unit.

Amplitude—The voltage level of a signal. Could be relative (e.g., peak-to-peak for AC signals) or absolute (for DC signals).

Aspect ratio—In facsimile or television, the ratio of the width to the height of a picture, document, or scanning field. NTSC television has standardized the aspect ratio at 4:3 (i.e., the picture is wider than it is high by a factor of 1 1/3). If an image is not reproduced at the intended aspect ratio, objects in the image are distorted.

Automatic iris control—An automatic control that regulates the amount of light that reaches the video pickup unit.

Auxiliary jacks—Any of a number of connectors that a piece of video equipment can have to allow it to be connected to and interwork with other equipment.

Bandwidth—The difference between the limiting frequencies within which performance of a device, in respect to some characteristic, falls within specified limits. An analogy to bandwidth might be the width of a street or a highway, where each lane is a radio frequency.

Black balance—See white balance.

Blue-only control—A switch that turns off the red and green electron guns in a monitor. This allows for the monitor to be calibrated based on the signal from the blue gun only.

Bookmark—A feature of recorders that allows the user to quickly find the end of previously recorded material so that additional recording can resume from that point.

Brightness—A qualitative attribute of visual perception in which a source appears to emit a given amount of light. In monitors, overall brightness is dependent on the high-voltage level and the DC grid bias.

Broadcast quality—A generic descriptor indicating that a piece of equipment is of sufficient quality to be used regularly by the broadcast television industry. Typically, the requirement is that resolution be greater than 450 TVL.

Cathode ray tube (CRT)—The vacuum (electron) tube that generates an image in a television monitor using cathode-ray electrons.

Charge coupled device (CCD)—Small light-to-electric-charge transducers placed in rectangular arrays on silicon wafers and used as video pickup devices. The signal is read out from the array sequentially from side-to-side and top-to-bottom to determine one video frame.

Chrominance—In color television, that signal or portion of the composite signal that bears the color information.

Clarity—A qualitative term generally referring to the combination of resolution, contrast, and color accuracy.

Color—Having a non-white spectral characteristic.

Comb filter—A filter that helps to minimize the loss of resolution and reduce streaking and wavy edges on fine patterns. Common in middle-range to high-end television displays and monitors.

Contrast—In display systems, the relation between (1) the intensity of color, brightness, or shading of an area occupied by display elements, a display group, or a display image on the display surface of a display device; and (2) the intensity of an area not occupied by a display element, a display group, or a display image. For a monitor, contrast is determined by the peak-to-peak amplitude of the video signal.

Contrast maximization (CM)—A technique for autofocusing cameras based on maximizing the contrast of the video signal.

Counter—In cameras and recorders, counters are used to keep track of tape position between start and finish. Counters can be in arbitrary units, time counting up, or time counting down.

dB (decibels)—(1) Ten times the common logarithm of the ratio of relative powers (P), equal to 0.1 bel. The formula is given by $dB = 10 \log[10] (P[1]/P[2])$; (2) Twenty times the common logarithm of the ratio of relative voltages (V) or currents (I), equal to 0.1 bel. The formula is given by $dB = 20 \log[10] (V[1]/V[2])$ for voltage and $dB = 20 \log[10] (I[1]/I[2])$ for current.

Dichroic lens—A lens in a camera that splits the incoming light into the three primary colors (red, green, and blue) so they can be picked up by separate CCDs or different areas on one CCD.

Digital storage oscilloscope (DSO)—An electronic test instrument used primarily for making visible the instantaneous value of one or more rapidly varying electrical quantities as a function of time or of another electrical or mechanical quantity. Its storage function allows several values to be recorded (and displayed together).

Digital zoom—A feature of digital cameras whereby they use only a portion of the pickup device and magnify the image to fill the full frame.

Distance—The position of the subject relative to the camera.

Dynamic contrast control—An automatic control to maximize the contrast of a scene. Generally, use of dynamic contrast control produces an improvement in overall picture quality.

Edit controller—A jack on a piece of equipment that allows it to be precisely controlled by another device for the purpose of editing tapes.

Electron beam spot size—The diameter of the focused electron beam that causes the phosphor on a monitor screen to fluoresce.

Electron tube—A vacuum tube designed to focus and direct beams of electrons. A common type of electron tube is a television picture tube (i.e., a CRT).

Electronic shutter—Use of electronics to simulate placing a shutter in front of a video pick-up device.

Environmentally robust—A manufacturer's subjective claim that their equipment can operate in a variety of temperature, humidity, lighting, and physically abusive conditions.

Fade—A nonabrupt interruption of the signal. In video, this generally refers to a graceful transition from one video signal to another.

Filters—In electronics, a device that transmits only part of the incident energy and may thereby change the spectral distribution of energy.

Flying erase head—In recorders, a recording technique that allows for a single frame to be erased from a videotape and then immediately replaced with a frame from another source. This allows for smooth transitions between scenes.

Focus—The mechanism used to ensure that the scene produces a sharp image on the video pickup device.

Gain-up—A control to increase the gain on the output of the video pickup device in low-light situations.

High definition television (HDTV)—Television that has approximately twice the horizontal and twice the vertical emitted resolution specified by the NTSC standard. Typically, these systems provide about 1,125 lines of horizontal resolution and an aspect ration of 16.9, for image quality approaching 35mm photography.

High-speed shutter—A physical or electronic shutter that operates at faster than 1/60 sec.

Hue—The visible spectral content of an image or part of an image that depends on the phase angle of the chrominance signal. The phase is varied with respect to a color-synchronizing signal by a "tint" or "hue" control. This control is subjectively set for the correct hue of any known color on the screen (e.g., green grass or blue sky); then, all other hues are automatically corrected, since the color synchronization holds all hues in the proper phase with respect to each other.

Image stabilization—A camera feature to reduce the visible effects of shake and wobble introduced by hand holding the camera. Two techniques are currently used to accomplish this. The first is through the use of a deformable prism. As the camera/lens detects shake and vibration, the prism is reshaped to provide stability to the image. The second is to electronically remove the effects of shake and distortion by modifying the output signal from the pickup device.

Index—A feature that "marks" the videotape each time recording is started, enabling the user to easily find a particular recorded section of tape.

Infrared light (IR)—The region of the electromagnetic spectrum bounded by the long-wavelength extreme of the visible spectrum (approximately 0.7 mm) and the shortest microwaves (approximately 0.1 mm).

Infrared playback—See wireless playback.

Inputs—The types of signals that a device can receive and the connectors through which those signals are received.

Intensifier—A device placed in front of a camera pickup device that amplifies available light from a scene.

IR ranging—An autofocus technique that uses an infrared signal to determine the optimum focusing distance.

Iris—The adjustable physical opening that light passes through en route to the video pickup unit.

Intermediate frequency (if)—A frequency to which a carrier frequency is shifted as an intermediate step in transmission or reception.

LANC—Edit control interface for high-end consumer equipment.

Lens compatibility—Indicates a camera that has many interchangeable lenses, including interchangeability with those of other manufacturers.

Lens mount—The physical connection between the lens and the camera. The most common lens mount for video cameras is the "C" mount.

Light (1)—In a strict sense, the region of the electromagnetic spectrum that can be perceived by human vision, that is, the visible spectrum, which is the wavelength range of approximately 0.4 to 0.7 mm.

Light (2)—An attachment for a camera to help illuminate scenes where available light is too low to allow recording of a satisfactory image.

Liquid crystal display (LCD) monitor—A viewing device for a camera that is based on liquid crystal display technology and is 2 to 4 in. in size.

Low light—Low-light cameras typically have published minimum acceptable light levels of between 0.1 and 2 lux.

Lumen (lm)—(1) The unit of luminous flux. The luminous flux emitted within unity solid angle by a point source having a uniform intensity of one candela; (2) SI unit of luminous flux. Radiometrically, it is the luminous flux emitted within a unit solid angle by a point source having a uniform luminous intensity of one candela.

Luminance—In color television, that signal or portion of the composite signal that bears the brightness information.

Lux—A measure of light intensity, which is used in photography for the comparison of camera sensitivities. One lux is equivalent to the light level incident on a 1 square meter area when a lumen of light is distributed across it. One footcandle = 10.76 lux.

Macro mode—A special mode for some lenses that allows focusing at closer distances than normal to provide greater magnification of a small object or detail on a larger object.

Microphone holder—A bracket on a camera that allows for the attachment of an external microphone.

Minimum illumination—The minimum ambient light level (usually given in lux) required to give the camera a sufficient signal to make an "acceptable" picture. Each manufacturer has a different definition of acceptable.

Monitor bridging—A mode in which a monitor can receive and display a video signal and then pass it on to another device without modification.

Motion sensor—An automatic sensor in a camera that allows the system to be activated when motion is detected and deactivated at a specified interval after motion ceases.

Multiple heads—Refers to recording equipment making use of more than one electromagnetic device attached to spinning drums inside the VCR. In video playback units, multiple heads improve the image quality during high-speed and slow-motion playback.

Multiple mounting holes—Two or more tapped holes for mounting the camera (e.g., on a tripod or wall-mounted bracket). More holes allow different size (and weight) lenses to be accommodated while keeping the assembly balanced.

National Television System Committee (NTSC)—Denotes the board that set the original standards for American television; also used as a reference to the television standard they published.

Noise—A disturbance that affects a signal and may distort the information carried by the signal or, loosely, any disturbance tending to interfere with the normal operation of a device or system.

Noise reduction—Using filtering or digital signal processing techniques to reduce the amount of noise in an image. Noise reduction figures of 6 dB are common.

NTSC video—The North American standard (525-line, interlaced, raster-scanned video) for the generation, transmission, and reception of television signals. (Note: In addition to North America, the NTSC standard is used in Central America, a number of South American countries, and some Asian countries, including Japan.)

Optical zoom—The zoom achieved by a lens.

Phase—Of a periodic, varying phenomenon (e.g., an electrical signal or electromagnetic wave); any distinguishable instantaneous state of the phenomenon, referred to a fixed reference or another periodic varying phenomenon. [Note: The phase of a periodic phenomenon can also be expressed or specified by angular measure, with one period usually encompassing 360° (2 pi radians).]

Photo mode—That mode of operation of a videotape recorder in which it "captures" a single frame of video and records that one frame for 6 to 10 sec on the videotape, essentially making a still photo on the videotape.

Pixel—In a raster-scanned imaging system, the smallest discrete scanning line sample that can contain gray scale information. An abbreviation for picture element.

Playthrough—The condition of taking a known input, passing it through a device, and comparing the output of the device with that known input.

Radio frequency (rf)—Any frequency within the electromagnetic spectrum normally associated with radio wave propagation. Normally, information signals are modulated to be transmitted at a rf.

Radio frequency tuner—The part of a circuit that can be adjusted to resonate at a particular frequency. Allows "channels" to be received from broadcast or cable systems.

Remote control—A device that is detached from the main piece of equipment, yet provides a mechanism for the user to control that piece of equipment. The two most common types of remote control are wired and wireless. Wired remotes require a physical connection (via wire) from the remote control to the main chassis. Wireless remotes typically use an infrared signal to communicate between the remote control and the main chassis.

Resolution—A measurement of the smallest detail that can be distinguished by a video system or device under specific conditions.

RGB (red-green-blue)—Pertains to the use of three separate signals to carry the red, green, and blue components, respectively, of a color video image.

RS-170A (EIA-170)—An Electronic Industries Alliance (EIA) standard describing a black and white television system containing 525 lines in two interlaced fields at a field rate of 59.94 Hz. This is the basis of the modern, North American NTSC television system.

Saturation—In video systems, the level of color relative to the maximum handling capacity for that color. The level of saturation is dependent on the level of the chrominance component of the video signal.

Scan rate—The frequency at which the electron beam scans a single line of an image. This is 15.7 kHz for an NTSC system and can be as high as 100 kHz for computer monitors.

Screen size—The diagonal dimension of a display screen (measured in inches or centimeters). Sometimes part of a display screen may be hidden behind a plastic housing (i.e., the case of the display), thus causing a mismatch between the published screen size and the viewable screen size.

Self-timer—A feature of a video recorder that allows it to turn itself on and/or off at a particular time or time interval.

Sensitivity—In an electronic device (e.g., a communications system receiver such as a television), the minimum input signal required to produce a specified output signal having a specified signal-to-noise ratio or other specified criteria.

Shutter—A device that opens and closes, allowing or not allowing light to reach the video pickup device.

Signal—Detectable transmitted energy that can be used to carry information.

Signal-to-noise ratio (SNR)—The ratio of the amplitude of the desired signal to the amplitude of noise signals at a given point in time. [Note: SNR is usually expressed in

dB (20 times the logarithm of the amplitude ratio or 10 times the logarithm of the power ratio) and in terms of peak values for impulse noise and root-mean-square values for random noise. In defining or specifying the SNR, both the signal and noise should be characterized (e.g., peak-signal-to-peak-noise ratio) to avoid ambiguity.]

Speaker—An electrical signal-to-audio sound pressure transducer.

Special effects (special FX)—Any number of features added by camera manufacturers that affect the video in special ways; includes fades, wipes, and solarization.

Still video—Recording a single frame of video to several seconds of videotape, essentially creating a still image that can be annotated with audio (i.e., use of the audio recording tracks to record information about the picture).

Super VHS (S-VHS)—The same as standard VHS except that the luminance carrier is shifted to a higher frequency, allowing for greater carrier bandwidth and, hence, greater resolution (about 400 TVL).

S-VHS–C—A piece of equipment using S-VHS videotape in a smaller cassette.

Synchronization signal—A signal used to synchronize pieces of video equipment to a common clock. In medium- and large-sized video facilities it is necessary to synchronize all pieces of equipment to avoid problems when recording or playing video.

Tagged image file format (TIFF)—A standardized file format used to store images.

Time lapse—The technique of recording one frame at a time at specified intervals. When played back at normal speed, time appears compressed, allowing for viewing of a whole day's worth of video in just a few minutes.

Tint—See hue.

Titling—Referring to the ability to overlay text or symbols onto a video signal. An example of titling is credits at the beginning or end of a movie.

Video—An electrical signal containing timing (synchronization), luminance (intensity), and often chrominance (color) information that, when displayed on an appropriate device, gives a visual image or representation of the original image sequences.

Videocassette recorder (VCR)—Denotes all formats of videotape recorder except reel-to-reel.

Video home system (VHS)—Videocassette record/playback tape format using ½-in. videotape and a cassette approximately 4 by 7 ½ in.

VHS–C—A piece of equipment using standard VHS videotape in a smaller cassette.

Viewfinder compatibility—Implies that a camera has a jack to which an LCD monitor can be attached.

White balance—A camera device that controls the overall intensity of a video signal. Most cameras come with an automatic white balance adjustment that can be overridden in situations where the content of the scene is not "average" (i.e., the subject is either lighter or darker than average).

Wind screen—A device (typically sponge rubber) that is used to cover a microphone and prevent wind from striking the diaphragm and causing extraneous (usually annoying) noise while still allowing sound waves to pass through, creating an audio signal.

YIQ—Luminance, In-phase, Quadrature (the letter Y is commonly used in video work as a symbol for luminance).

**Source*: Reference 10.

APPENDIX A

Synthesis Questionnaire

ELECTRONIC SURVEILLANCE TECHNOLOGY ON TRANSIT VEHICLES

Name and title of person completing questionnaire: _____

Agency: _____ Phone number: _____

Address: _____

_____

INSTRUCTIONS: *For multiple choice questions, please check all answers that apply.*

A. BACKGROUND INFORMATION

1. How many revenue vehicles does your agency operate?

a. Bus _____
b. Heavy Rail _____
c. Light Rail _____
d. Paratransit _____
e. Other (please describe): _____

2. How many annual unlinked passenger boardings do you provide?

a. Bus _____
b. Heavy Rail _____
c. Light Rail _____
d. Paratransit _____
e. Other (please describe): _____

3. What are your agency's annual passenger revenue totals for each mode of service you provide?

a. Bus $ _____
b. Heavy Rail $ _____
c. Light Rail $ _____
d. Paratransit $ _____
e. Other (please describe): _____ $ _____

4. Is your agency self-insured? A. Yes ❑ b. No ❑

B. SURVEILLANCE SYSTEM INFORMATION

5. Does your agency use a surveillance system on board revenue vehicles?

a. Yes ❑ b. No ❑

If the answer is "No" please proceed to question # 28.

6. What type of surveillance system?

a. CCTV cameras ❑ b. Black Boxes ❑ c. Audio Pickup ❑

If your agency does not use CCTV cameras on board revenue vehicles, please proceed to question # 11.

7. What is the format of the CCTV system? a. Digital ❑ b. Analog ❑

8. What is the make/model of the surveillance equipment your agency has purchased *(e.g., combination of Sony Model XXX and Model YYY cameras, Panasonic Model A VCRs, with Model B multiplexer)*?

_____

_____

9. What equipment options does your CCTV system have?

a. Multi-camera system ❑
b. 24-hour recording ❑
c. Automatic emergency digital transmission ❑
d. Multiplexing ❑
e. Surge protection ❑
f. Power filter or conditioner ❑
g. Secondary power source ❑
h. Vandal-proof housing ❑
i. Auto-start ❑
j. Color images ❑
k. Other _____

10. Is the vehicle equipped with an indicator that informs the driver if the surveillance system becomes incapacitated in any way? a. Yes ❑ b. No ❑

C. APPLICATIONS

11. Has there been a measurable reduction in vandalism since the installation of the surveillance system?
a. Yes ❑ b. No ❑

12. Has there been a measurable reduction in the number of assaults since the installation of the surveillance system? a. Yes ❑ b. No ❑

13. Has there been a measurable reduction in the number of fraudulent claims since the installation of the surveillance system? a. Yes ❑ b. No ❑

14. Has there been a measurable increase in rider perceptions of security since the installation of the surveillance system? a. Yes ❑ b. No ❑

15. Has there been a measurable increase in operator perceptions of security since the installation of the surveillance system? a. Yes ❑ b. No ❑

16. Rate how effective (overall) you feel the surveillance system has been at reducing crime *(1 is most effective and 7 is least effective)*

(most) 1 2 3 4 5 6 7 (least)
❑ ❑ ❑ ❑ ❑ ❑ ❑

17. Rate how effective you feel the system has been in assisting in making criminal convictions *(1 is most effective, 7 is least effective, and N/A indicates that system is not used for this purpose)*

(most) 1 2 3 4 5 6 7 N/A
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

18. For what other purposes has your agency used the system?

a. Fare Dispute Mediation ❑
b. Complaint Resolution ❑
c. Employee Monitoring ❑
d. Other _____

19. Rate how effective you feel the system has been for these purposes *(1 is most effective, 7 is least effective, and N/A indicates that system is not used for this purpose)*

19a. Fare Dispute Mediation
(most) *1 2 3 4 5 6 7 N/A*
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

19b. Complaint Resolution
(most) *1 2 3 4 5 6 7 N/A*
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

19c. Employee Monitoring
(most) *1 2 3 4 5 6 7 N/A*
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

19d. Other (Please describe): _____
(most) *1 2 3 4 5 6 7 N/A*
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

20. Has your agency ever used recordings to attempt to prove claims against the system are fraudulent?
a. Yes ❑ b. No ❑

21. Rate the effectiveness of the system at reducing fraudulent claims against the system *(1 is most effective, 7 is least effective, and N/A indicates that system is not used for this purpose)*
(most) *1 2 3 4 5 6 7 N/A*
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

22. Has your agency ever used recordings from the surveillance system as evidence in court?
a. Yes ❑ b. No ❑

23. If your agency currently uses, or plans to use, on-board surveillance technology in conjunction with *overt* security operations, what types of operations are in use (or planned)?
a. On-board security personnel ❑ b. Trailing vehicle ❑
c. Other _____

24. If your agency currently uses, or plans to use, on-board surveillance technology in conjunction with *covert* security operations, what types of operations are in use (or planned)?
a. On-board undercover security personnel ❑
b. Undercover trailing vehicle ❑
c. Other _____

D. PROCEDURES

25. Does your agency archive recordings made on revenue vehicles? a. Yes ❑ b. No ❑

25a. If "yes," how long do the recordings remain in the archives? _____

26. What percentage of your fleet is outfitted with surveillance devices?
a. Less than 25% ❑ c. 51–75% ❑
b. 25–50% ❑ d. 76–100% ❑

27. If less than 100%, which vehicles were chosen to be outfitted with surveillance technology?
a. Vehicles on high crime routes ❑ c. Newer vehicles ❑
b. Vehicles transporting large numbers of juveniles ❑ d. Other _____

E. SYSTEMS WITHOUT ON-BOARD SURVEILLANCE TECHNOLOGY

28. If your agency does not use on-board surveillance technology, are you considering procuring such a system?

a. Yes ❑ b. No ❑

28a. *If "yes," what type of surveillance system(s) are you considering?*

a. CCTV cameras ❑ c. Audio Pickup ❑
b. Black Boxes ❑ d. Other _____

28b. *If "no," why not?*

a. Unnecessary ❑ c. Legal issues ❑
b. Too expensive ❑ d. Other_____

28c. *If "no," under what circumstances would your agency consider purchasing on-board surveillance technology?*

a. Reduction in cost ❑ c. Resolution of legal issues ❑
b. Increased need for surveillance ❑ d. Other _____

F. LEGAL & PRIVACY CONCERNS

29. Are privacy issues related to on-board surveillance technology a significant concern or problem for your agency?

a. Yes ❑ b. No ❑

29a. *If "yes," how does your agency plan to address privacy issues?*

a. Community Input ❑ c. Legal Advice ❑
b. Employee Input ❑ d. Other _____

30. Does your agency use, or plan to use, signage which notifies the riding public of the use of on-board surveillance technology?

a. Yes ❑ b. No ❑

30a. *If "yes," what information will the signage convey?*

a. The possibility of surveillance ❑ c. Other _____
b. The certainty of surveillance ❑

30b. *If "yes," what is/will be the exact wording of the signage?*

_____
_____
_____

31. If employees at your agency belong to a union, do you solicit input from union representatives on the subject of on-board surveillance?

a. Yes ❑ b. No ❑

31a. *If "yes," what concerns have been addressed by union representatives?*

a. Employee privacy concerns ❑ c. Employee safety ❑
b. Employee liability ❑ d. Other _____

32. Has your agency enlisted community support for on-board surveillance?

a. Yes ❑ b. No ❑

32a. If "yes," how was the support enlisted?
a. Advertisement campaign ❑
b. On-board and/or station signage ❑
c. Other _____

G. COSTS

Instructions: *Some of the answers to the questions in this section can be expressed in terms of either dollars or hours, please use whichever you feel conveys the most accurate picture of cost.*

33. How did your agency obtain the funds to pay for the surveillance system?
a. FTA grant program ❑
b. State grant program ❑
c. Local funds ❑
d. Internal funding source ❑
e. Other _____

34. What was the purchase price of the on-board surveillance system? _____

35. Was installation included in the purchase price? a. Yes ❑ b. No ❑

36. As new vehicles come on-line, are they outfitted with on-board surveillance?
a. Yes ❑ b. No ❑

36a. *If "yes," what is the cost of outfitting each vehicle with surveillance equipment?* _____

36b. *Is installation included in this cost?* a. Yes ❑ b. No ❑

37. What are the approximate monthly maintenance costs associated with the system? _____

38. What are the approximate monthly training costs associated with the system? _____

39. What are the approximate monthly vehicle downtime costs associated with the system? _____

40. What are the approximate monthly archiving costs associated with the system? _____

41. What are the approximate monthly management costs associated with the system? _____

H. PROBLEMS

42. What effect does on-board surveillance have on fleet availability?
a. No effect ❑
b. Minimal effect ❑
c. Some effect ❑
d. Considerable effect ❑

43. What are the most significant weaknesses of the system?
a. ❑ Picture quality *(explain)*: _____
b. ❑ Maintenance requirements *(explain)*: _____
c. ❑ Tape archiving requirements *(explain)*: _____
d. ❑ Downtime *(explain)*: _____
e. ❑ Cost *(explain)*: _____

I. RECOMMENDATIONS

44. If another transit system, similar to your own, asked whether they should install an on-board surveillance system on their fleet would you advise them to do so?

a. Yes ❑ b. No ❑

44a. *If "yes," why?* _____

44b. *What would you suggest the agency do differently than your agency?* _____

44c. *What would you suggest the agency do the same as your agency?* _____

44d. *If "no," why not?* _____

PLEASE FAX COMPLETED QUESTIONNAIRE BY JULY 31, 2000 TO: *(804) 985-8977*

Or mail to:
Boyd, Maier & Associates, Inc.
402 Greenwood Farms Road
Barboursville, VA 22923

IF YOU HAVE QUESTIONS REGARDING THE SURVEY, PLEASE CONTACT:
Pat Maier: (804) 985-1033
THANK YOU FOR YOUR PARTICIPATION

APPENDIX B

Responses to the Questionnaire

NOTE: Most of the multiple choice questions below could have more than one answer.

1. How many revenue vehicles does your agency operate? (Totals)

Bus	17,738
Heavy Rail	3,812
Light Rail	613
Paratransit	1,862
Other	246
Total Respondents	*32*

2. How many annual unlinked passenger boardings do you provide? (Totals in millions)

Bus	1,491
Heavy Rail	658
Light Rail	149
Paratransit	7
Other	97
Total Respondents	*32*

3. What are your agency's annual passenger revenue totals for each mode of service you provide?

Inadequate data

4. Is your agency self-insured?

Yes	25
No	2

5. Does your agency use a surveillance system on board revenue vehicles?

Yes	25
No	7

6. What type of surveillance system?

CCTV cameras	17
Event Recorders	13
Audio Pickup	3
Total Respondents	*24*

7. What is the format of the CCTV system?

Digital	17
Analog	6
Total Respondents	*21*

8. What is the make/model of the surveillance equipment your agency has purchased?

Total Respondents *17*

9. What equipment does your CCTV system have?

Automatic emergency digital transmission	0
Other	2
Power filter or conditioner	5
Secondary power source	5
24-hour recording	9
Multiplexing	11
Surge protection	13
Color images	12
Auto-start	16
Vandal-proof housing	18
Multi-camera system	20
Total Respondents	*21*

10. Is the vehicle equipped with an indicator that informs the driver if the surveillance system becomes incapacitated in any way?

Yes	11
No	10

11. Has there been a measurable reduction in vandalism since the installation of the surveillance system?

Yes	13
No	7

12. Has there been a measurable reduction in the number of assaults since the installation of the surveillance system?

Yes	10
No	9

13. Has there been a measurable reduction in the number of fraudulent claims since the installation of the surveillance system?

Yes	6
No	9

14. Has there been a measurable increase in rider perceptions of security since the installation of the surveillance system?

Yes	10
No	7

15. Has there been a measurable increase in operator perceptions of security since the installation of the surveillance system?

Yes	12
No	8

16. Rate how effective (overall) you feel the surveillance system has been at reducing crime (1 = most effective, 7 = least effective).

Total: 3.4 (20 scores, 1 N/A response)

17. Rate how effective (overall) you feel the surveillance system has been in making criminal convictions (1 = most effective, 7 = least effective).

Total: 3.4 (15 scores, 5 N/A responses)

18. For what other purposes has your agency used the system?

Fare dispute mediation	3
Complaint resolution	8
Employee monitoring	3
Other	6
Total Respondents	*20*

19. Rate how effective you feel the system has been for these purposes

19a. *Fare Dispute Mediation* (1 = most effective, 7 = least effective).

Total: 3.6 (5 scores, 14 N/A responses)

19b. *Complaint Resolution* (1 = most effective, 7 = least effective).

Total: 3.6 (9 scores, 10 N/A responses)

19c. *Employee Monitoring* (1 = most effective, 7 = least effective).

Total: 3.5 (6 scores, 14 N/A responses)

19d. *Other* (1 = most effective, 7 = least effective).

Total: 2.8 (5 scores, 4 N/A responses)

20. Has your agency ever used recordings to attempt to prove claims against the system?

Yes	10
No	12

21. Rate the effectiveness of the system at reducing fraudulent claims against the system. (1 = most effective, 7 = least effective).

Total: 2.9 (11 scores, 9 N/A responses)

22. Has your agency ever used recordings from the surveillance system as evidence in court?

Yes	9
No	10

23. If your agency currently uses, or plans to use, on-board surveillance technology in conjunction with overt security operations, what types of operations are in use (or planned)?

On-board security personnel	7
Trailing vehicle	2
Other	4
Total Respondents	*9*

24. If your agency currently uses, or plans to use, on-board surveillance technology in conjunction with covert security operations, what types of operations are in use (or planned)?

On-board undercover security personnel	9
Undercover trailing vehicle	3
Other	3
Total Respondents	*10*

25. Does your agency archive recordings made on revenue vehicles?

Yes	10
No	13

26. What percentage of your fleet is outfitted with surveillance devices?

Less than 25%	11
25–50%	6
51–75%	3
76–100%	3
Total Respondents	*23*

27. If less than 100%, which vehicles were chosen to be outfitted with surveillance technology?

Vehicles on high crime routes	5
Vehicles transporting large numbers of juveniles	10
Newer vehicles	13
Other	5
Total Respondents	*21*

28. If your agency does not use on-board surveillance technology, are you considering procuring such a system?

Yes	6
No	2

28a. If "yes," what type of surveillance system(s) are you considering?

CCTV cameras	5
Black boxes	0
Audio Pickup	1
Other	0
Total Respondents	*5*

28b. If "no," why not?

Unnecessary	0
Too expensive	1
Legal issues	1
Other	0

28c. If "no," under what circumstances would your agency consider purchasing on-board surveillance technology?

Reduction in cost	0
Increased need for surveillance	1
Resolution of legal issues	0
Other	0

29. Are privacy issues related to on-board surveillance technology a significant concern or problem for your agency?

Yes	7
No	21

29a. If "yes," how does your agency plan to address privacy issues?

Community input	2
Employee input	6
Legal advice	5
Other	3
Total Respondents	*16*

30. Does your agency use, or plan to use, signage which notifies the riding public of the use of on-board surveillance technology?

Yes	23
No	3

30a. If "yes," what information will the signage convey?

The possibility of surveillance	12
The certainty of surveillance	6
Other	2
Total Respondents	*20*

30b. If "yes," what is/will be the exact wording of the signage?

Responses to Question 30b are located elsewhere in this synthesis.

31. If employees at your agency belong to a union, do you solicit input from union representatives on the subject of on-board surveillance technology?

Yes	19
No	4

31a. If "yes," what concerns have been addressed by union representatives?

Employee privacy concerns	14
Employee liability	2
Employee safety	11
Other	1
Total Respondents	*19*

32. Has your agency enlisted community support for on-board surveillance?

Yes	8
No	18

32a. If "yes," how was the support enlisted?

Advertisement campaign	2
On-board and/or station signage	1
Other	3
Total Respondents	*5*

33. How did your agency obtain the funds to pay for the surveillance system?

FTA grant program	14
State grant program	9
Local funds	6
Internal funding source	6
Other	1
Total Respondents	*24*

34. What was the purchase price of the on-board surveillance system?

Insufficient data

35. Was installation included in the purchase price?

Yes	8
No	1

36. As new vehicles come on-line, are they outfitted with on-board surveillance?

Yes	14
No	8

36a. If "yes," what is the cost of outfitting each vehicle with surveillance equipment?

The mean of the 13 responses is $6,500

36b. Is installation included in the cost?

Yes	15
No	1

37. What are the approximate monthly maintenance costs associated with the system?

Inadequate data

38. What are the approximate monthly training costs associated with the system?

Inadequate data

39. What are the approximate monthly vehicle downtime costs associated with the system?

Inadequate data

40. What are the approximate monthly archiving costs associated with the system?

Inadequate data

41. What are the approximate monthly management costs associated with the system?

Inadequate data

42. What effect does the surveillance system have on fleet availability?

No effect	16
Minimal effect	6
Some effect	0
Considerable effect	0
Total Respondents	*22*

43. What are the most significant weaknesses of the system?

Picture quality	7
Maintenance requirements	9
Tape archiving requirements	2
Downtime	1
Cost	1
Total Respondents	*13*

44. If another transit system, similar to your own, asked whether they should install an on-board surveillance system on their fleet would you advise them to do so?

Yes	23
No	1

44a. If "yes," why?

- Passengers benefit from the system.
- Although the technology is rather new, I believe in its effectiveness.
- It works well.
- Crime deterrence is the main benefit.
- The system is useful for fraudulent claims, complaints, accidents.
- Depends on what issues they wish to address.
- The presence of cameras deters bad behavior. People are on notice that crime is not tolerated.
- It is a helpful, excellent tool even if results aren't always measurable.
- Increased ridership because passengers feel safer. Increased operator perceptions of security.
- May decrease fraudulent claims; may improve rider behavior.
- It has reduced vandalism.
- The new technologies have decent picture quality; color digital cameras have great potential to assist law enforcement and fraud prevention.
- It is a good product and will be a positive thing.
- Sends message to employees that we care for their safety; systems help curb passenger behavior.
- Better able to keep control of vehicles and see what is going on.
- System could provide an excellent tool for accident investigation and customer complaints.
- When operating fine, it's your best line of defense.
- The system has resulted in significant liability reductions.
- Based on information we have on-hand, CCTV equipped buses will reduce criminal activity.
- Enhances public image of safety and acts as a deterrent to crime.
- Has strong effect on kids.

APPENDIX C

Questionnaire Respondents

AC Transit District—Oakland, CA
Antelope Valley Transit Authority—Lancaster, CA
Bay Area Rapid Transit District—San Francisco, CA
Bi-State Development Agency—St. Louis, MO
Central Ohio Transit Authority—Columbus, OH
Charlotte Transit—Charlotte, NC
Chicago Transit Authority—Chicago, IL
Durango LIFT—Durango, CO
Golden Empire Transit District—Bakersfield, CA
Greater Cleveland Regional Transit Authority—Cleveland, OH
Island Transit—Coupeville, WA
King County/Metro—Seattle, WA
Lakeland Area Mass Transit District—Lakeland, FL
Massachusetts Bay Transportation Authority—Boston, MA
Mass Transit Administration—Baltimore, MD
Mass Transportation Authority—Flint, MI
Metropolitan Transit Authority—Houston, TX
Metro Transit—St. Paul, MN
Miami Valley Regional Transit Authority—Dayton, OH
Milwaukee County Transit System—Milwaukee, WI
Montgomery County Ride-On—Rockville, MD
New Jersey Transit—Maplewood, NJ
Niagara–Frontier Transportation Authority—Buffalo, NY
Regional Transit—Sacramento, CA
Regional Transit District—Denver, CO
San Francisco MUNI—San Francisco, CA
Santa Monica's Big Blue Bus—Santa Monica, CA
SunLine Transit Agency—Thousand Palms, CA
Torrance Transit—Torrance, CA
Valley Transit—Appleton, WI
VIA Metropolitan Transit—San Antonio, TX
Washington Metropolitan Area Transit Authority—Washington, DC

APPENDIX D

Surveillance Equipment Details*

VIDEO RECORDER/PLAYERS FEATURES

Auto/manual focus—Automatic focus will change the focus based on the perceived target and maintain it until something changes. Even if autofocus is available, professionals will often use manual focus in instances where there is a chance that the automatic feature will have trouble differentiating the target image from other activity.

Auto/manual white balance—Automatic white balance will maintain the optimum color balance in either indoor or outdoor conditions. Manual control is useful if unique conditions exist that the auto white balance feature cannot deal with (e.g., strong backlight).

Bookmark search—With this feature, one may return to the point where recording had previously ended.

Day/time setting—A built-in calendar and clock allows each recording to be "stamped." A "button cell" battery keeps the date and time correct.

Enclosures—Every VCR requires an enclosure of some type to protect the unit from dust and debris. This enclosure normally has a fan for heating and cooling. Because the VCR is mounted inside the bus, a fan is usually sufficient since the bus must be internally heated or cooled for passenger comfort. Some systems have internal heaters that allow the temperature of the VCR to be raised quickly so that recording can be accomplished before the bus is warmed up. A protection circuit to keep the VCR from recording at low or high temperatures is useful, because if the VCR is triggered to record at these unacceptable temperatures damage may occur. The enclosure must be rigidly mounted to prevent theft and high vibration. Most enclosures include some padding for protection against bumps. It is recommended that the VCR enclosure have shock absorbing to promote long life on the soldering and mechanical parts. The enclosure is generally lockable, with not even the driver having the key. Metal is the preferred material, but high impact plastic is also acceptable.

Flying erase head—Allows user to make exceptionally clean edits of the videotape. Video and audio "dubbing" (i.e., changing) is possible.

Headphone jack—Usually a one-eighth in. stereo phono jack.

Image stabilization—Optical or electrical.

Index search—An index mark can be placed at the beginning of each recording so that automatic review and playback can be more easily accomplished.

Light source—Built-in or accessory.

Motion sensor—Useful for situations requiring constant surveillance, but where a low activity rate does not justify constant recording. A motion sensor activates the recording function. Audio sensors are also available.

Mounting/installation—The camera is sometimes an integral part of the VCR enclosure. In this instance, the entire unit is usually mounted on the ceiling of the bus. Often, the enclosure is mounted under or behind the seat of the driver, allowing for easy access, and room is usually available there for easy mounting.

Multiple heads for still frames/slow motion playback—Video head design is an area where significant improvements have been made in the past 5 years. In simple systems, one video head is required to record and playback the video track. Multiple heads have been added to improve quality at different speeds, with some units automatically switching the output from head to head to maximize the amount of signal that can be recovered from a tape. As a result, noise-free still frames and slow motion effects can be produced. It is also possible to have less noise (snow) in the picture scan mode.

Noise reduction—Improves the picture quality in marginal lighting situations.

Remote controls—Typically using wireless technology, remote control devices can start and stop recording and even control zoom functions.

Sensitivity/gain-up controls for shadows—"Sensitivity/gain-up" controls or buttons are intended to increase the brightness in scenes where needed. The better sensitivity mechanisms have made shadowed images 50 to 80 percent brighter with little increase in noise or distortion (graininess in the image).

Tape and time counter—Displays a number reading for the position on the tape or the elapsed time during a recording. Time remaining may also be displayed.

Titling—Annotations of various lengths and types can be added to the tape.

VIDEO CAMERA FEATURES

The following is a list of features that are offered in video cameras. At a minimum, auto/manual white balance, auto-iris control, lens compatibility, multiple mounting holes, and environmental robustness are desirable features.

Auto-iris control—For auto-iris lenses, an automatic gain control (AGC) or variable gain (e.g., 6 dB)—selectable on/off.

Dynamic contrast control—Allows accommodation of scenes with a much wider range of light levels than normal (e.g., allows detail in both sun-lit and shadowy areas of the same scene).

Electronic shutter—Enables the camera to produce clear images in still or slow motion playback, even when the objects are moving at very high speeds.

Enclosure—All cameras installed in buses must have some type of enclosure or be mounted in some existing panel or compartment. The most common are installed in rugged cases to avoid vandalism. Such enclosures must be installed away from airbags and high enough not to be in the way of passengers. Some dome types and wedge types are made of a high-impact soft material that are designed to avoid injury to passengers, but that can withstand abuse. Some small pcb board cameras can be installed in existing sign boxes or other places that already exist in the bus.

Environmentally robust—Typical requirements for environmentally robust equipment include operation over a wide temperature range (e.g., 14°F to 122°F), storage over a wide temperature range (e.g., –22°F to 158°F), operation at high altitude (e.g., 10,000 ft) and in heavy relative humidity (e.g., 95 percent), and tolerance of shock and vibration.

Filters—Built-in optical filters can improve video results under various lighting conditions (e.g., bright, subdued, inside, outside).

Flashing lights—Some cameras come with lights or LEDs, which are illuminated when the camera has power. Some even flash to give the illusion the system is recording. Both of these features are useful and help convince the passenger that the system is in operation. Although lights are important as a deterrent, they are unnecessary for the actual recording system operation.

Lens compatibility—Accepts all (or most) types of manual and auto-iris television lenses.

Lens mount—Adjustable C-mount (adapter).

Microphone holder—An adjustable ring or other type of connection apparatus provided on the camera to mount a microphone.

Multiple mounting holes—Two or more tapped holes for mounting the camera (e.g., on a tripod or wall-mounted bracket). More holes allow different size (and weight) lenses to be accommodated while keeping the assembly balanced.

Power options—AC or DC power options, typically 12 V DC, 24 V DC, or 115 V AC.

Power up with VCR—A feature that is useful and power saving is to have the VCR turn on the camera. This makes power management and battery usage efficient. Powering the camera from the VCR makes for a simple cable harness supplied by the vendor, which eases installation. Also, this powering also enables the system to record after the operator has left the bus and then goes to the low battery drain mode. For systems that connect directly to the ignition, the powering of the camera via the VCR is unnecessary.

Resolution—Because most VCRs that record in buses have 230–240 line resolution in the SP Mode (2 hr) and even lower in the EP Mode (6 hr), the resolution of the camera is not a significant purchase criteria. This is because almost all cameras have a minimum of 380 lines of resolution (black and white) or 300 lines of resolution (color). As long as the camera resolution exceeds that of the VCR, the picture will be the best the VCR can record.

RGB adjustments—Independent gain controls on red, green, and blue outputs. Remote control of red, green, blue, and master gain (i.e., overall video signal level).

Synchronization options—Internal (crystal) or external source.

White balance and/or black balance—Automatic, manual, or remote control switch selectable. External white or black balance sensor is possible.

OTHER FEATURES

Cameras do not usually come as part of an all-inclusive video package. Additional components must be purchased for the system to function. A few of the most

common items required for the camera system, but not normally supplied with it, are listed here:

- AC power pack or AC/DC power supply;
- Lens;
- Coaxial cables (e.g., RG-59/U) for connections to the recorder or monitor from the "video out" jack, from camera to external sensor or synchronization, for remote control, etc.; and
- Television monitor for focusing and other adjustments (such as white balance).

Source: Reference 10.

APPENDIX E

SEPTA Passenger Survey

SEPTA PASSENGER SURVEY

1. Are your aware that video cameras are recording what is happening inside your bus?
   Yes ❑ No ❑

2. Do you approve of video surveillance inside your bus?
   Yes ❑ No ❑ Don't Know ❑

3. Do you feel safer with video surveillance inside your bus?
   Yes ❑ No ❑ Don't Know ❑

4. Do you consider the video cameras a bus service improvement?
   Yes ❑ No ❑ Don't Know ❑

5. Do you think that passengers act more responsibly when there are cameras on the bus?
   Yes ❑ No ❑ Don't Know ❑

6. How often do you ride the bus?
   Every day ❑
   Almost every day ❑
   Sometimes ❑

7. Your age: less than 25 ❑ 25 to 35 ❑
   36 to 50 ❑ Over 50 ❑

8. Your sex: Male ❑ Female ❑

ANY COMMENTS:

_____

_____

Thank you for your assistance! Please drop in any mailbox

APPENDIX F

SEPTA Operator Survey

ROADRECORDER TRIAL

DRIVER EVALUATION SURVEY

1. Do you like the idea of having video cameras on your bus?

   Yes_____ No_____ Don't Know_____

2. Do the video cameras on your bus make you feel safer?

   Yes_____ No_____ Don't Know_____

3. Do you think that video cameras on your bus affect the passengers actions?

   Yes_____ No_____ Don't Know_____

4. Do you think that the passengers act more responsibly when there are cameras on your bus?

   Yes_____ No_____ Don't Know_____

5. Do you think that the passengers like the cameras on your bus?

   Yes_____ No_____ Don't Know_____

6. Have your passengers made any comments to you about the video cameras?

   Yes_____ No_____ Don't Know_____

   If yes, what were they? (use back of form if necessary) _____

7. Would you like to see cameras on all of the buses?

   Yes_____ No_____ Don't Know_____

ANY COMMENTS:

APPENDIX G

SEPTA Specific Incident Form

SEPTA
SPECIFIC INCIDENT FORM
Legal Custody Document

Route/Block Number: _____

Vehicle Number: _____

Date of Accident: _____

Time of Removal: _____

Operator Name (Print): _____

Claims File Number: _____

District: _____

Incident Number: _____

Unit Serial Number: _____

Operator Account Number: _____

CHAIN OF CUSTODY			
DATE & TIME RECEIVED	PRINT NAME	RECEIVED BY (signature, acct.# & location)	Received from/ Removed From Bus

Directions for Filling Out the Chain of Custody Portion of This From

At the Scene of an Incident:

1. The person retrieving the drive canister from the RoadRecorder should enter the date, time and bus number in the spaces provided. This person should also enter his/her signature, account number, and incident location under the column labeled "Received BY". This individual's name must also be printed in the column provided.

Handling Thereafter:

2. Whoever receives the drive from the supervisor should place his/her signature and account number in the "Received By" column on the next line. The receiver must print his/her name in the column provided. In all instances, this and subsequent receivers should verify all information (especially the unit serial number) on this sheet before accepting custody.

3. The receiving supervisor should then place the name of the person from whom he/she is receiving the disk in the column marked "Received From".

Accuracy:

4. Accuracy in completing this Chain of Custody document is essential. Any litigation in this case could be jeopardized as a result of inaccuracies/inconsistencies in preparing this form. Please check and review all information/data during the transfer process.

INCIDENT.FRM