

EVOLUTION OF CCTV: FROM TRADITIONAL SURVEILLANCE TO AI BASED COMMERCIAL SECURITY

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1. INTRODUCTION

A closed-circuit television system, also known as Closed Circuit Television, refers to a security system whereby video cameras capture images and relay them to a select group of receivers such as monitors³. In contrast to standard broadcast television, Closed Circuit Television restricts access to a select few individuals⁴. This system is ideally suited for the surveillance of homes, schools, hospitals, and even whole cities⁵. Since its advent, Closed Circuit Television has had a variety of uses. Examples include perimeter surveillance and traffic analysis. In perimeter surveillance, one monitors the external perimeter of a certain building. In traffic analysis, on the other hand, one monitors driving behavior and movement⁶. Closed Circuit Television has long remained the premier solution to modern-day security challenges. Some of its benefits include constant surveillance, its capacity to serve as a deterrent to crime, and providing vital information during investigations⁷. Technological advances, such as facial recognition software, have further improved the application of Closed Circuit Television.

1.1.THE ORIGIN OF THE CAMERA:

The camera is at the core of all closed-circuit television systems because it is what makes the process of capturing visual data possible⁸. The term camera comes from the Latin expression camera obscura, which means dark room, an allusion to the early optical instruments that used light and lenses to project images⁹. The age of electronic imaging started in 1969 with the development of the charge-coupled device by George Smith and Willard Boyle from Bell Labs. Although initially created as a

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³ Clive Norris, Jade Moran & Gary Armstrong, *Surveillance, Closed Circuit Television and Social Control* 1–5 (Ashgate Publ'g Ltd. 1998).

⁴ David Lyon, *Surveillance Studies: An Overview* 24–31 (Polity Press 2007).

⁵ Martin Gill & Angela Spriggs, *Assessing the Impact of CCTV*, Home Office Research Study No. 292, at 1–10 (Home Office 2005).

⁶ U.K. Home Office, *Closed Circuit Television (CCTV): Operational Requirements Manual* 15–20 (2009).

⁷ Brandon C. Welsh & David P. Farrington, Effects of Closed-Circuit Television Surveillance on Crime, 18 *Campbell Systematic Reviews* 1, 3–8 (2009).

⁸ Herman Kruegle, *CCTV Surveillance: Video Practices and Technology* 1–8 (2d ed. Butterworth-Heinemann 2007).

⁹ John H. Hammond, *The Camera Obscura: A Chronicle* 3–12 (Adam Hilger Ltd. 1981).

type of memory storage device, the charged coupled device would later transform photography, videography, and surveillance through electronic imaging.

1.2.EARLY SURVEILLANCE TECHNOLOGY STALIN TO THE V-2 ROCKET:

THE SOVIET UNION:

According to several historical accounts, one of the earliest experimental surveillance systems was developed in the Soviet Union during the late 1920s and early 1930s under Joseph Stalin's administration. The system has been attributed to Léon Theremin, the Russian inventor best known for creating the electronic musical instrument known as the theremin. It reportedly consisted of a camera connected to a closed-circuit television receiver and was intended for government surveillance purposes. Owing to the classified nature of the project, little technical information was publicly available at the time. The first widely documented modern Closed Circuit Television system was later developed in Germany by Walter Bruch for Siemens in 1942, marking a significant milestone in the evolution of video surveillance technology.¹⁰

GERMANY:

In 1942, German engineer Walter Bruch developed one of the earliest documented closed-circuit television systems for Siemens AG. The system was designed primarily to allow Nazi scientists and military personnel to observe V-2 rocket launches at the Peenemünde Army Research Center from a safe distance without being exposed to the hazards associated with rocket testing¹¹. Following the Second World War, the United States military adopted similar closed-circuit television technology to monitor nuclear weapons testing and other hazardous military operations.¹²

2. BIRTH OF COMMERCIAL SURVEILLANCE CAMERAS:

2.1.FIRST PUBLIC CLOSED CIRCUIT TELEVISION CAMERAS:

In 1949, the American company Vericon introduced one of the first commercially available closed-circuit television systems. These early surveillance systems represented a significant advancement in commercial security technology. However, they lacked the capability to record video footage and

¹⁰ Herman Kruegle, *CCTV Surveillance: Video Practices and Technology* 3–6 (2d ed. Butterworth-Heinemann 2007).

¹¹ Clive Norris, Jade Moran & Gary Armstrong, *Surveillance, Closed Circuit Television and Social Control* 13–15 (Ashgate Publ'g Ltd. 1998).

¹² David Lyon, *Surveillance Studies: An Overview* 22–25 (Polity Press 2007).

therefore required continuous human monitoring.¹³ Unless an operator was actively observing the monitor, the system could not preserve visual information for subsequent review or evidentiary purposes.¹⁴

2.2.VIDEO TAPE RECORDER:

In 1951, the development of the videotape recorder (VTR) marked a significant advancement in electronic imaging and surveillance technology.¹⁵ Early open-reel videotape recorders enabled live television images to be recorded on magnetic tape and replayed at a later time, thereby overcoming the limitations of earlier closed-circuit television systems that relied solely on real-time monitoring.¹⁶ The first commercially successful videotape recorder, the Ampex VRX-1000 (later renamed the Mark IV), was introduced in 1956.¹⁷ The machine was approximately the size of a table and cost nearly US\$50,000, making it affordable primarily to television broadcasting organizations and large institutions.

3. PUBLIC CLOSED CIRCUIT TELEVISION SURVEILLANCE: 1950s-1960s: THE CORONATION OF QUEEN ELIZABETH II (1953):

The coronation of Queen Elizabeth II in 1953 marked one of the earliest large-scale public applications of closed-circuit television for security and crowd management. Closed Circuit Television cameras were deployed to assist law enforcement authorities in monitoring the event, demonstrating the growing potential of surveillance technology in ensuring public safety during major public gatherings.

LONDON TRANSPORT AND TIMES SQUARE (1960s):

During the early 1960s, Closed Circuit Television technology began to be adopted for public security and crowd management. In 1961, Closed Circuit Television cameras were installed at selected London Transport stations to enhance passenger safety and assist in surveillance. By the mid-1960s,

¹³ Kruegle, *supra* note 1, at 9.

¹⁴ David, *supra* note 1, at 10.

¹⁵ Alexander B. Magoun, *Television: The Life Story of a Technology* 107–10 (Greenwood Press 2007).

¹⁶ Albert Abramson, *The History of Television, 1942 to 2000* 127–35 (McFarland & Co. 2003).

¹⁷ Ampex Corp., *Ampex and the Development of Videotape* (Corporate Historical Archives); Alexander B. Magoun, *supra* note 1, at 108–10.

New York City had also introduced Closed Circuit Television cameras in Times Square as part of its efforts to improve urban security and monitor public spaces.¹⁸

OLEAN, NEW YORK (1968):

In 1968, the City of Olean, New York, became one of the first municipalities in the United States to install Closed Circuit Television cameras along its main street for law enforcement purposes. The live video feeds were transmitted directly to the local police station, enabling officers to monitor public activity in real time. However, the system lacked an integrated recording capability, meaning that evidence could not be preserved unless personnel continuously monitored the footage or expensive videotape recorders (VTRs) were employed.

4. THE VIDEOCASSETTE REVOLUTION:-

A COMPACT, COST-EFFECTIVE SOLUTION (1969):

The introduction of videocassette technology during the late 1960s and early 1970s represented a significant advancement in video recording and surveillance systems. Unlike open-reel magnetic tapes, videocassettes were enclosed within protective plastic cartridges, making them more compact, durable, and easier to store and handle. Their design also simplified the process of changing recording media, thereby improving the efficiency of surveillance recording.¹⁹ The subsequent introduction of videocassette recorders (VCRs) for professional and consumer use during the early 1970s further expanded the practical application of Closed Circuit Television systems by enabling convenient recording, storage, and playback of surveillance footage.

THE FIRST VIDEO SECURITY SYSTEM FOR HOME USE:

Marie Van Brittan Brown and her husband, Albert Brown, are widely recognized as the inventors of one of the earliest home video security systems. Concerned about her personal safety while alone at home, Marie Brown designed an innovative security system comprising four peepholes, a sliding camera, a monitor, and a two-way intercom, allowing occupants to identify visitors without opening

¹⁸ Michael McCahill, *The Surveillance Web: The Rise of Visual Surveillance in an English City* 20–25 (Willan Publ'g 2002).

¹⁹ Erik Barnouw, *Tube of Plenty: The Evolution of American Television* 381–86 (2d ed. Oxford Univ. Press 1990).

the door.²⁰ The invention laid the foundation for the development of modern residential surveillance systems.

THE ARRIVAL OF CLOSED CIRCUIT TELEVISION: THE 1970s AND 1980s:

The widespread availability of improved Closed Circuit Television systems, combined with consumer-grade videocassette recorders (VCRs), contributed to the rapid expansion of surveillance technology during the 1970s and 1980s. Individuals, businesses, and public institutions could record, store, replay, and archive surveillance footage, making Closed Circuit Television a practical tool for security and evidence preservation.²¹

RETAIL AND FINANCIAL INSTITUTIONS:

By the mid-1970s and throughout the 1980s, Closed Circuit Television systems equipped with VCRs became increasingly common in retail stores, banks, and other financial institutions. These systems were primarily used to deter theft, monitor employee and customer activities, and provide recorded evidence for criminal investigations. Early surveillance cameras were generally large and highly visible, reflecting the technological limitations of the period.²²

LOW LIGHT AND NIGHT VISION (1976):

The commercial development of charge-coupled device (CCD) imaging technology during the 1970s significantly improved Closed Circuit Television performance under low-light conditions. By enabling cameras to capture clearer images in poorly illuminated environments, CCD technology paved the way for modern night-vision surveillance systems.²³

²⁰ U.S. Patent No. 3,482,037 (filed Aug. 1, 1966) (issued Dec. 2, 1969); Herman Kruegle, *CCTV Surveillance: Video Practices and Technology* 10–12 (2d ed. Butterworth-Heinemann 2007).

²¹ Herman Kruegle, *CCTV Surveillance: Video Practices and Technology* 12–16 (2d ed. Butterworth-Heinemann 2007); Albert Abramson, *The History of Television, 1942 to 2000* 211–20 (McFarland & Co. 2003).

²² Martin Gill & Angela Spriggs, *Assessing the Impact of CCTV*, Home Office Research Study No. 292, at 3–7 (Home Office 2005); Clive Norris, Jade Moran & Gary Armstrong, *Surveillance, Closed Circuit Television and Social Control* 18–21 (Ashgate Publ'g Ltd. 1998).

²³ Gerald C. Holst, *CCD Arrays, Cameras, and Displays* 1–18 (2d ed. JCD Publ'g 1998); George E. Smith, *A Passion for Discovery: My Life Among the Quantum Giants of Bell Labs* 145–55 (Prometheus Books 2010).

CAMERA DESIGNS THAT WERE SMALLER AND SLIMMER: As camera designs became better and cameras grew smaller, less ostentatious designs came into being. Dome and bullet cameras are just two examples of such cameras.

5. THE DIGITAL REVOLUTION:

THE LIMITATIONS OF ANALOG TECHNOLOGY (LATE 1980S - EARLY 1990s):

The transition from analog to digital imaging accelerated during the 1990s with significant advances in digital camera technology and image compression. Kodak introduced commercially significant digital imaging systems during this period, while the development of the Ampex Digital Component Technology (DCT) compression format in 1993 greatly improved digital video storage and transmission.²⁴ The introduction of the Apple QuickTake 100 in 1994 further expanded access to digital photography by making consumer digital cameras more widely available.²⁵

THE COMING OF DIGITAL TECHNOLOGY (LATE 1990s):

Kodak released multiple digital devices in 1987. Digital video compression became viable in 1993 through the Ampex DCT. The Apple QuickTake 100 made digital photography accessible in 1994.

Advantages of digital cameras²⁶ included:

- High-quality imaging
- Media did not deteriorate over time, unlike videocassettes
- High storage capability
- Storage media such as hard disks and flash storage could store days, weeks, or even months of media
- Virtually limitless cloud storage
- Unlimited storage potential through reuse of hard disk space

DIGITAL MULTIPLEXERS AND DVRS (MID-1990s):

²⁴ Alexander B. Magoun, *Television: The Life Story Of A Technology* 126–32 (2007).

²⁵ Albert Abramson, *The History Of Television, 1942 To 2000* 445–52 (2003).

²⁶ Herman Kruegle, *CCTV Surveillance: Video Practices And Technology* 31–39 (2d ed. 2007).

The creation of digital multiplexers during the mid-1990s made it possible for a digital video recorder (DVR) to record video footage from several cameras at once. It is because of this invention that multiple camera security systems have become commonplace.

6. SPECIALIZED CAMERAS:

Cameras grew more specialized and compact. In 1992, the first nanny cam was invented.

THE FIRST IP CAMERA (1996):

In 1996, the first IP camera was born: the Axis NetEye 200. Unlike other cameras that needed a wired connection, it could send footage without any wires by connecting it to a computer network. This camera is the immediate predecessor of today's webcams and surveillance cameras.²⁷

MODERN SURVEILLANCE CAMERAS:

Modern surveillance cameras incorporate numerous technological advancements, including high-definition imaging, wireless connectivity, weather-resistant construction, infrared night vision, intelligent motion detection, integrated audio recording, and remote monitoring through Internet-based platforms. These developments have significantly enhanced the effectiveness of Closed Circuit Television systems in crime prevention, public safety, and evidence collection. Research has also indicated that the visible presence of surveillance cameras may reduce criminal activity, particularly property offences such as theft and vandalism.²⁸

CCTV CAMERA TYPES:

Different surveillance environments require different categories of Closed Circuit Television cameras depending upon the operational objectives, field of view, lighting conditions, and monitoring requirements. Common types include dome cameras, bullet cameras, pan-tilt-zoom (PTZ) cameras, box cameras, 360-degree (fisheye) cameras, day/night cameras, infrared (IR) cameras, licence plate recognition (LPR/ANPR) cameras, wireless cameras, and covert surveillance cameras.²⁹

²⁷ Axis Commc'ns AB, *The History of Network Video: The World's First Network Camera* (1996), <https://www.axis.com/about-axis/our-history>; Herman Kruegle, *CCTV Surveillance: Video Practices and Technology* 27–31 (2d ed. Butterworth-Heinemann 2007).

²⁸ Brandon C. Welsh & David P. Farrington, *Effects of Closed-Circuit Television Surveillance on Crime*, 24 Campbell Systematic Rev. 1, 16–20 (2009); Martin Gill & Angela Spriggs, *Assessing the Impact of CCTV*, Home Office Research Study No. 292, at 33–38 (Home Office 2005).

²⁹ Herman Kruegle, *CCTV Surveillance: Video Practices and Technology* (2d ed. Butterworth-Heinemann 2007).

7. THE EVOLUTION FROM ANALOG TO DIGITAL:

ANALOG CCTV (PRE-2000s):

- Low resolution (standard definition or lower)
- Basic functionalities; video transmitted via coaxial cables
- Footage recorded on VHS tapes or other analog media

TRANSITION PHASE (LATE 1990s - EARLY 2000s):

- Introduction of digital video recorders (DVRs)
- Improved storage, search, and retrieval
- Some systems combined analog cameras with digital recording

DIGITAL CCTV (MID-2000s ONWARD):

- IP cameras captured and transmitted digital video over computer networks
- Higher resolutions, including megapixel and high-definition options
- Remote access to live feeds and recorded footage via the internet
- Advanced features: motion detection, facial recognition, PTZ capabilities
- Network video recorders (NVRs) replaced DVRs for more advanced video management

HIGH DEFINITION AND BEYOND (2010s ONWARD):

- HD and 4K cameras improved image quality dramatically
- Infrared technology advanced for better low-light performance

INTEGRATION WITH AI AND ANALYTICS (2010s ONWARD):

- Artificial intelligence enabled advanced video analytics—facial recognition, object tracking, behavioral analysis³⁰
- Machine learning algorithms improved system efficiency and accuracy over time

CLOUD-BASED SOLUTIONS (2010s ONWARD):

³⁰ S. Kevin Zhou & Rama Chellappa, eds., *Handbook of Pattern Recognition and Computer Vision* 487–520 (5th ed., World Scientific 2016); Marcus Böhm, *Artificial Intelligence in Video Surveillance* 41–68 (Springer 2020).

- Cloud storage enabled remote access without extensive on-site infrastructure
- Cloud solutions offered scalability and flexibility

The shift from analog to digital has not only improved image quality and storage but has also enabled intelligent features that make surveillance more effective and adaptable³¹.

7.1. APPLICATIONS OF CCTV BEYOND TRADITIONAL SECURITY:

Closed Circuit Television systems serve a wide variety of purposes beyond conventional security. Here are some notable applications:

- Traffic Monitoring
- Smart Transportation
- City Planning and Development
- Environmental Monitoring
- Retail and Business Operations
- Educational Institutions
- Industrial Applications
- Tourism and Hospitality
- CCTV and Crowd Management
- Event Surveillance
- Public Spaces
- Entertainment Venues
- Retail Environments
- Protests and Public Gatherings
- Educational Institutions
- Tourist Attractions
- Hospitality Venues

7.2. BENEFITS OF CCTV SURVEILLANCE SYSTEMS:

Installing a Closed Circuit Television system offers a range of advantages including Security Deterrence that helps in discourage potential criminals and intruders in visible cameras.³² It also

³¹ Brandon C. Welsh & David P. Farrington, Effects of Closed-Circuit Television Surveillance on Crime, 17 Campbell Systematic Rev. 1 (2021); Herman Kruegle, CCTV Surveillance: Video Practices and Technology 213–254 (2d ed., Butterworth-Heinemann 2007).

helps in crime prevention which helps in monitoring and recording help prevent theft, vandalism, and other crimes.

Further the benefits of Closed Circuit Television surveillance system helps in incident documentation that supports investigations and clarifies events in Visual evidence. It also supports employee and visitor safety, a secure environment protects everyone on the premises and benefits in 24/7 Monitoring leading to continuous surveillance ensures round-the-clock vigilance.

- Operational Oversight - Monitoring day-to-day operations helps identify inefficiencies and ensure compliance.
- Remote Access - Footage can be viewed from anywhere, improving responsiveness³³.
- Risk Reduction - Early identification of threats allows for timely intervention.³⁴
- Insurance Benefits - Some insurers offer reduced premiums for properties with CCTV.
- Peace of Mind - Both management and occupants feel more secure.

The evidence on Closed Circuit Television's effectiveness is nuanced. Research suggests that Closed Circuit Television is more effective in some contexts than others, and more effective against certain types of crime. Studies consistently show that Closed Circuit Television has a greater impact on property crimes particularly thefts from and of vehicles than on personal crimes such as assault. Research on whether Closed Circuit Television makes people feel safer is mixed. Some studies find that Closed Circuit Television increases feelings of safety; others suggest that cameras mainly make those who already feel safe feel even safer. Relatively few people report changing their behavior because of Closed Circuit Television.

In various studies, only 8–22% said they would use public areas more as a result of feeling safer. Importantly, many people simply don't notice the cameras at all. The deterrent effect of Closed Circuit Television depends on offenders' awareness and perceptions. Some research suggests that publicizing the presence of cameras increases their deterrent effect. Interviews with offenders reveal

³² Martin Gill & Angela Spriggs, *Assessing the Impact of CCTV*, Home Office Research Study No. 292, at 18–27 (Home Office 2005).

³³ Axis Commc'ns AB, *The History of Network Video*, <https://www.axis.com/about-axis/our-history> (last visited July 7, 2026).

³⁴ Brandon C. Welsh & David P. Farrington, *Effects of Closed-Circuit Television Surveillance on Crime*, 17 Campbell Systematic Rev. 1, 21–29 (2021).

a generally blasé attitude toward Closed Circuit Television though those who have been caught on camera are more likely to view it as a threat. As more offenders are caught and word spreads, the perceived risk may increase.