CCTV Video Surveillance and Crime Control: The Current Evidence and Important Next Steps

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Abstract
Closed-Circuit Television (CCTV) video surveillance cameras have become a popular crime control tool around the world. While the diffusion of CCTV initially occurred absent a scientific knowledge base, the technology has since become well researched. A body of literature comprising of mostly quasi-experimental evaluation studies has evolved to the point that three systematic reviews and meta-analyses have been conducted since the early 2000s. Overall findings from the research literature are highly nuanced. This chapter provides a primer on the current state of CCTV research. It discusses key considerations pertaining to CCTV research methodology and the scientific evidence on CCTV’s crime control capacity. It concludes with a discussion of important knowledge gaps and key takeaways for practitioners and policymakers.

Keywords:
CCTV; video surveillance; crime-and-place; crime prevention; case clearance; research methodology

Citation:
In the Criminal Justice Process and Policy course I taught for the John Jay College doctoral program from 2016 to 2020 I became notorious among students for frequently uttering “it’s not a refrigerator” during discussions on whatever crime control technology was in vogue. This comment was meant to criticize standard operating procedure surrounding criminal justice technology deployment. The refrigerator is effective through simplicity. The user plugs the unit into an electric outlet, fills it with groceries, and never has to think about the inner-workings of refrigeration to realize the goal of keeping beverages cold and food fresh. Crime prevention technology is not nearly as straightforward. Whether or not technology delivers the intended crime prevention benefits depends on a range of contextual factors, inclusive of the technological infrastructure, implementation capacity of the public safety agency, social setting in which technology interventions take place, and the manner by which officers use technology in practice (Ariel, 2019; Lum, Koper, & Willis, 2017; Salvemini, Piza, Carter, Grommon, & Merritt, 2015). Unfortunately, criminal justice practitioners oftentimes deploy technology absent any consideration of such contextual factors needed to maximize the likelihood of success. They set up the technology and expect it to achieve the intended goals on its own.

My “it’s not a refrigerator” refrain is applicable to most crime control technology, but is particularly appropriate in the case of closed-circuit television (CCTV) video surveillance cameras. Because it cannot physically block access to certain areas or safeguard individual objects or people, CCTV relies on perceptual mechanisms by which potential offenders believe camera presence substantially heightens the risk associated with crime commission (Ratcliffe, 2006). While lay persons (and even some “experts”) may assume conspicuous camera presence alone sufficiently communicates heightened risk, such causal mechanisms can be difficult to generate in practice (Gannoni, Willis, Taylor, & Lee, 2017; Martin Gill & Loveday, 2003; Piza,
Caplan, & Kennedy, 2014b). The nuanced nature of the CCTV literature reflects this reality. While the overall body of research finds CCTV can generate significant (albeit modest) crime reductions, effects are highly contextual, contingent on a range of geographic and programmatic factors (Piza, Welsh, Farrington, & Thomas, 2019; Welsh & Farrington, 2002, 2009). The research evidence becomes further mixed when alternate outcomes such as case closure and cost effectiveness are considered (Piza, 2021).

This chapter provides a primer on the current state of research on CCTV. It begins by discussing key considerations pertaining to CCTV research methodology. A critical overview of the research evidence follows. The chapter concludes with a discussion of important knowledge gaps in the literature and key takeaways for practitioners and policymakers.

I. METHODOLOGICAL CONSIDERATIONS

A. Units of Analysis

A challenge with CCTV research is operationalizing areas receiving “treatment.” As previously mentioned, CCTV effect on crime rests on a causal mechanism by which potential offenders identify cameras and view the cameras as increasing the likelihood of detection and apprehension (Ratcliffe, 2006). As such, CCTV is grounded in deterrence and rational choice perspectives, and seeks to increase formal surveillance within specific areas targeted by the video cameras (Cornish & Clarke, 2003). CCTV is a place-based intervention, and representing offender perceptions geographically is difficult, if not impossible. As argued by Ratcliffe, Taniguchi, & Taylor (2009, 751) “the difficulty with offender perceptions is that they are not measurable without extensive and expensive interviewing. Furthermore, the resultant offender perception will most likely vary from person to person. In other words, while the range of a CCTV camera—as perceived by a criminal—is in the eye of the beholder, finding and
interviewing suitable beholders is beyond the budget of most studies, and the results are likely to be quite variable.” The challenge for researchers is to operationalize CCTV target areas in a manner that maximizes the overlap between potential offenders’ conception of “space” and a CCTV camera’s line of sight.

CCTV target areas have been operationalized a number of different ways in the literature. Much CCTV research has considered aggregate areas containing CCTV cameras, such as neighborhoods or police districts, as target areas (e.g., Jang, Kim, Park, & Kim, 2018; Prenzler & Wilson, 2019; Sivarajasingam, Shepherd, & Matthews, 2003; Squires, 1998). An alternate popular approach has been to use circular buffer areas around CCTV camera locations as the unit of analysis (Cameron, Kolodinski, May, & Williams, 2008; King, Mulligan, & Raphael, 2008; Lim, Kim, Eck, & Kim, 2016; Mazerolle, Hurley, & Chamlin, 2002). Researchers have argued that both of these approaches may compromise construct validity (Caplan, Kennedy, & Petrossian, 2011; Ratcliffe et al., 2009).

Given that CCTV cameras have the capacity to view limited distances, using areas such as “districts” or “neighborhoods” as the unit of analysis likely vastly overestimates CCTV coverage. Furthermore, preexisting administrative boundaries may make poor units of analysis for social science research because they are drawn to facilitate service delivery and are not necessarily representative of the behavior clusters that are of interest for surveillance (Piza, Caplan, & Kennedy, 2014a). While buffer zones truncate the size of target areas, they inaccurately depict CCTV coverage by assuming a 360 degree, unobstructed line of sight for each camera. This is rarely, if ever, the reality of a real-word environment, with features such as street signs, trees, and buildings commonly obscuring a camera’s line of sight (Piza et al., 2014a). Buffers may be particularly susceptible to the modifiable aerial unit problem, as
reflected by the wide range of radius distances prior CCTV research has used when creating buffers (see Kronkvist, 2022, Table 2).

More recent CCTV research has used viewsheds to operationalize CCTV camera target areas. Viewsheds estimate the actual area within a CCTV camera’s line-of-sight, incorporating natural constraints to visibility such as trees or buildings (Ratcliffe et al., 2009). Viewsheds can further enable researchers to readily measure micro-level factors to ensure comparability between treatment and control units. Viewsheds reflect the larger trend in crime-and-place research to incorporate more micro-level units of analysis in recognition that they better reflect the spatial patterns of variables of interest (Oberwittler & Wikstrom, 2009) and account for variance more efficiently than does the use of larger units of analysis (Schnell, Braga, & Piza, 2017; Steenbeek & Weisburd, 2015).

To the author’s knowledge, Ratcliffe and colleagues’ (2009) evaluation of 18 pilot CCTV cameras in Philadelphia, Pennsylvania was the first to use viewsheds. Ratcliffe and colleagues (2009) visited the CCTV viewing station, working with police officers to digitize individual viewsheds by panning and zooming the cameras and discussing active viewing areas with the officers. Viewshed distances were typically set as the limit where a street-sign could be read.¹ A 500-foot buffer around the viewsheds were designated as the displacement area. Control areas were designated as the surrounding police districts beyond the displacement area. Ratcliffe & Groff’s (2019) longitudinal analysis of Philadelphia’s fully deployed 192-camera system took a similar approach to designating viewshed, displacement, and control areas.

In their analysis of the first 73 cameras installed in Newark, New Jersey, Caplan, Kennedy, & Petrossian (2011) expanded the viewshed methodology by developing a method to

¹ This information was gleaned from personal communication with Ratcliffe on April 13, 2022.
operationalize viewsheds when researchers do not have access to CCTV camera feeds. Caplan and colleagues (2011) first created 582-foot (approximately the length of 2 city blocks in Newark) buffers around each camera location. Viewsheds were then digitized within a Geographic Information System (GIS) by drawing polygons within the 582-foot buffer and excluding areas that were blocked by obstructions visible from the aerial imagery. Caplan and colleagues (2011) operationalized control areas by randomly generating 73 points on street segments in a GIS and then repeating the aforementioned viewshed creation process for each. This differs from most other CCTV evaluation studies using viewsheds, which typically use one operationalization for target sites (i.e. viewsheds) and another for comparison sites (e.g. police districts, cameras buffers, etc.) (La Vigne & Lowry, 2011; Lim & Wilcox, 2017; Ratcliffe & Groff, 2019; Ratcliffe et al., 2009).

Piza (2018) combined the direct observation (Ratcliffe & Groff, 2019; Ratcliffe et al., 2009) and aerial imagery (Caplan et al., 2011) viewshed approaches in his evaluation of the fully deployed 146-camera CCTV system in Newark. Piza (2018) viewed the live feeds all CCTV cameras and digitized the viewshed of each site within a GIS. Aerial map imagery and a detailed base map (with layers depicting streets, land parcels, and building footprints) were incorporated to ensure digitized viewsheds reflected the physical landscape by accounting for visible obstructions. Catchment zones of 291 feet (approximately the median block length in Newark) were created around each viewshed to allow for a test of spatial displacement. For all street intersections falling outside of CCTV viewsheds and catchment zones (N=961), Piza (2018) repeated the viewshed creation process to create a pool of control cases for the evaluation, with the final set of control selected through statistical matching.
Kronkvist's (2022) recent examination of CCTV in Malmö, Sweden demonstrates how unit of analysis operationalization can influence study results. Kronkvist (2022) generated different target, displacement, and control areas to test the effect of CCTV on violent and property crime in a residential neighborhood over a 5-year (2.5 years pre/post) study period. Target and control areas were operationalized as the camera’s encompassing small area for market statistics (SMAS) unit (classified by Statistics Sweden), a circular buffer around camera locations, and camera viewsheds. Catchment sites were operationalized as the SAMS contiguous to the target site and a buffer surrounding the target site. Most results were nonsignificant owing to low statistical power. When results were statistically significant, the triads of treatment/control/buffer areas produced varying results. Property crime either decreased significantly at control areas compared to target areas or remained unchanged, while violent crime decreased between 6% and 34% compared to control conditions depending on the triad used. The viewshed methodology was generally associated with null effect sizes. Kronkvist's (2022) findings suggest viewsheds may allow for more robust tests of CCTV than alternate units of analysis.

B. Experimentation and Quasi-Experimentation

Evidence-based crime prevention emphasizes the use of the best available research evidence to guide program development and implementation (Sherman et al., 1997). The strength of a given research study is largely related to its levels of internal, construct, and statistical conclusion validity (Welsh, 2019). Research designs incorporating comparable control conditions—namely, experiments and quasi-experiments—are privileged for their ability to protect against threats to these types of validity. Experiments, also referred to as Randomized Controlled Trials (RCTs), best reduce bias by randomly assigning cases to either treatment or control conditions, ensuring
these groups are statically equivalent across pertinent variables (Cook & Campbell, 1979; Farrington, Gottfredson, Sherman, & Welsh, 2006).

In many respects, the CCTV research literature is more robust than the research literature for crime prevention technology generally. Lum & Koper (2017) describe police technology as an example of “evidence-based policing playing catch-up,” in the sense that a much smaller pool of scientific evidence is available for technological interventions than officer-driven crime prevention strategies. Conversely, case-control CCTV evaluation studies have occurred often enough for three systematic reviews to have been conducted over less than a 20-year period (Piza et al., 2019; Welsh & Farrington, 2002, 2009). In other respects, CCTV research lags behind research on other contemporary police technologies. For example, the tangential video surveillance technology of police body-worn cameras has been evaluated through the frequent use of experimental and strong quasi-experimental designs (Lum et al., 2020; White & Malm, 2020). Conversely, 78 of the 158 (49.4%) evaluation studies identified for potential inclusion in the CCTV systematic review and meta-analysis were excluded most commonly for not incorporating suitable control conditions (Piza et al., 2019).

Practical considerations often necessitate the post-hoc evaluation of CCTV, forgoing random assignment. Given CCTV cameras are largely permanent fixtures, with cameras hard-wired to physical structures and wireless networks configured to stream footage to a centralized control room, changing target areas post-experimentation would incur significant financial costs (Piza, 2018). As such, practitioners install cameras at locations of their choosing, giving little to

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2 Redeployable CCTV cameras are an exception, given they can be moved quickly from place to place (Gill, Rose, & Collins, 2015). In addition to potentially facilitating rigorous research designs, this could provide a general cost savings as compared to permanent, hard-wired cameras (Verga & Douglas, 2008). However, redeployable CCTV does not seem to be used nearly as often as traditional CCTV. Research has also reported redeployable CCTV to commonly experience implementation failure (Gill et al., 2006).
no thought to the implications for research design (Piza, 2021). Nonetheless, researchers have incorporated RCTs in CCTV evaluations on three occasions. La Vigne & Lowry (2011) conducted a blocked randomized experiment, randomly assigning 100 parking lots operated by the Washington Metropolitan Area Transit Authority to receive digital cameras equipped with motion detectors or serve as a control case. Hayes & Downs (2011) assigned 47 large retail-store locations in the United States to receive one of three situational crime prevention treatments: in-aisle CCTV public view monitors, in-aisle CCTV domes, or polycarbonate protective safe boxes. Piza et al. (2015) incorporated a randomized block design to assign 38 clusters of CCTV viewsheds to either a treatment group receiving additional proactive CCTV monitoring and a team of directed patrol units or a control group receiving standard levels of CCTV monitoring and police patrol. While not a direct test of CCTV, because both treatment and control conditions had cameras, Piza et al.’s (2015) RCT tested the effect of better integrating CCTV with proactive policing functions.

Natural experiments are considered as high-quality alternatives to RCTs when random assignment is not possible. Natural experiments provide robust checks against endogeneity due to treatment occurring in a random or as-if random process, despite falling outside the direct control of researchers (Dunning, 2008). Such as-if random allocation of treatment distinguishes natural experiments from traditional quasi-experiments (Dunning, 2012). Alexandrie (2017) reviewed five natural experiments alongside the RCTs conducted by Hayes & Downs (2011) and La Vigne & Lowry (2011). Selection criteria differed across the review conducted by Alexandrie (2017) and those conducted by Piza et al. (2019) and Welsh & Farrington (2002, 2009). All five of the natural experiments reviewed by Alexandrie (2017)—published between the years 2008 and 2017—were excluded by Piza and colleagues (2019) due to the lack of separate control areas
in the research design. This illustrates the important role research designs play in the interpretation of evaluation study findings.

The CCTV evaluation literature is dominated by quasi-experimental designs, given the challenges associated with random assignment of treatment and capitalizing on naturally occurring as-if random processes. Of the 80 studies fitting the inclusion criteria of the most recent CCTV review, 76 (95%) used quasi-experimental designs (Thomas, Piza, Welsh, & Farrington, 2022). It is important to note that quasi-experiments vary in their levels of methodological rigor and internal validity. Quasi-experiments incorporate a nonequivalent control group design when steps are not taken to ensure that treatment and control conditions are similar on potentially confounding variables. Such nonequivalent quasi-experiments have a heightened risk of bias due to the presence of extraneous variables differing across treatment and control areas (Farrington et al., 2006). Bias caused by extraneous variables can be addressed by using statistical adjustments, such as matching (Rosenbaum, 2002). Matching attempts to generate equivalency between treatment and control conditions in the absence of randomization. Sixteen (20%) of the studies included in the most recent CCTV review used matching techniques to conduct quasi-experiments with near-equivalent control groups (Thomas et al., 2022). The precise nature of matching varied, from statistical algorithms such as propensity score matching (e.g., Piza, 2018) to manual matching of units based on similarities across factors such as crime levels, land usage, and neighborhood sociodemographic characteristics (e.g, Farrington et al., 2007; La Vigne, Lowry, Markman, & Dwyer, 2011). Three-quarters of the matched quasi-experiments and all of the aforementioned RCTs were conducted in the United States from 2011 onwards, reflecting a rapidly developing CCTV literature in this country (Thomas et al., 2022).
Irrespective of research design, causal analysis represents only the first step in policy analysis. The next step involves forecasting how well the evaluated program would perform in a new environment, which centers on considerations of external validity (Sampson, Winship, & Knight, 2013). External validity relates to the generalizability of a study’s findings. Eck (2017) distinguishes internal and external validity in terms of their differing foci. Internal validity is inherently retrospective, concerned with evaluating the quality of existing evidence, while external validity is prospective, primarily concerned with predicting what might occur in the future (i.e., if prior research findings will replicate when a practice is applied in a new jurisdiction). Systematic reviews and meta-analyses can help establish a program’s external validity because these efforts include all studies fitting a specified inclusion criteria. The studies included in a systematic review typically involve a range of different environments, treated populations, and operational definitions of the intervention (Welsh & Farrington, 2007). Unfortunately, while some meta-analyses provide explicit information on the contexts and causal mechanisms that undergird a program’s effect most do not (Tompson et al., 2021). When sufficient contextual information cannot be gleaned directly from a meta-analysis, agency personnel may be able to incorporate detailed observational information on the crime problem and tailor evidence-based practices to fit the nature of the problem at hand (Welsh, 2019). These types of efforts are key, as strict replication of programs is oftentimes impossible in real-world situations (Bardach, 2004).

II. THE RESEARCH EVIDENCE

A. CCTV and Crime Prevention

The collective knowledge of CCTV evaluation research is synthesized in the updated systematic review and meta-analysis of Piza and colleagues (2019), which updated the work of Welsh &
Farrington (2002, 2009). CCTV evaluation studies were selected for inclusion according to four criteria, as per the protocol of the Campbell Collaboration: 1) CCTV was the main focus of the intervention; 2) the evaluation used an outcome measure of crime; 3) the research design involved, at a minimum, before-and-after measures of crime in treatment and comparable control areas, and; 4) both treatment and control areas experienced at least 20 crimes during the pre-intervention period. Pooled effects across all studies included in the meta-analysis found crime decreased in CCTV areas by about 13% as compared to control areas. Achieved crime reductions were not negatively affected by displacement, as only 6 of the 50 studies incorporating adjacent control areas found any evidence of displacement.

Piza et al. (2019) found certain characteristics of CCTV systems were significantly associated with effect size, reflecting Welsh and Mear’s (this volume) argument that “context is everything” when assessing research evidence on crime and justice policy. Findings of Piza and colleagues’ (2019) meta-analysis indicate strategic considerations largely influence the effect of CCTV. Schemes incorporating active monitoring practices were associated with a significant crime reduction of approximately 15% while passively monitored systems did not generate any significant effects. Schemes incorporating multiple complementary interventions alongside CCTV were associated with a significant 34% reduction in crime with no significant effects observed for schemes deploying no or a single complementary intervention. A follow-up meta-analysis conducted by Welsh, Piza, Thomas, & Farrington (2020) found CCTV schemes operated by private security personnel generated larger crime prevention effects than those operated by police or those using a mix of police and security personnel.

Piza and colleagues (2019) found the strongest effects of CCTV within car parks (37% reduction), similar to the prior reviews (Welsh & Farrington, 2002, 2009). Contrary to the prior
reviews, Piza and colleagues (2019) found that CCTV schemes deployed in residential areas also generated significant crime reductions of approximately 12%. CCTV had the largest effect on drug crime (approximately 20% reduction), followed by reductions of approximately 14% for both vehicle crime and property crime, with no significant effects observed for violent crime. CCTV was associated with crime reductions in the United Kingdom and South Korea, with no significant effects observed for other countries. Thomas and colleagues (2021) noted that United Kingdom schemes more often incorporated contextual factors associated with increased likelihood of success—such as deployment in car parks, active camera monitoring, and the deployment of multiple complementary interventions alongside CCTV—as compared to CCTV schemes reported in other countries.

Several evaluation studies have found that CCTV effect can also vary within individual surveillance systems. Matczak, Wójtowicz, Dąbrowski, Leitner, & Sypion-Dutkowska (2021) found overall null effects of CCTV in Poland, though 10 of the 17 treatment areas showed evidence of a prevention effect as compared to control areas. Ratcliffe et al. (2009) found that just as many individual cameras had no effect as those that showed a benefit in Philadelphia, despite the aggregate system generating a 13.3% reduction in overall crime. Caplan et al. (2011) found that while motor vehicle theft was the only crime type to experience a system-wide reduction in Newark, each crime type included in the analysis decreased at between 34 and 58 individual cameras sites. The aggregate and camera-specific findings were largely replicated in analyses of Newark’s full 146-camera system (Piza, 2018; Piza et al., 2014a).

Research studies highlight specific contextual factors that may explain such intra-system variation in CCTV effect. Piza et al. (2014a) found the presence of certain facility types

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3 Piza and colleagues (2019) noted the small number of studies conducted in South Korea (n=3) call for caution in interpreting the magnitude of effects.
influenced CCTV effect in Newark. For example, the presence of bars was associated with reductions in violent crime and robbery. The presence of retail stores was associated with increases in property crime and theft from auto while the presence of schools was associated with increased levels of auto theft. Piza et al. (2014a) further uncovered significant effects of enforcement actions generated by proactive CCTV monitoring, which were associated with decreases in overall crime, violent crime, and theft from auto. Contextual effects of land usage were also found by Lim & Wilcox (2017) in Cincinnati. While Cincinnati’s overall CCTV system produced minimal crime prevention benefits, many individual camera sites in residential areas experienced reductions in assault, robbery, and burglary with diffusion of benefits observed much more often than displacement. In their evaluation of Detroit’s Project Green Light—an intervention in which volunteer businesses installed a minimum of four surveillance cameras, lighting, and signage identifying their participation in the program—Circo & McGarrell (2021) found gas stations experienced the most substantial increases in disorder and property crime over the first month of the program. Over the full post-intervention period, property crime generally decreased at liquor stores and retail stories and remained stable in bars and restaurants.

**B. CCTV and Case Clearance**

The majority of CCTV research solely focuses solely on the technology’s crime deterrence effects (Piza, 2021), with studies typically only reporting process measures and descriptive statistics on how CCTV cameras are used by investigators (see e.g., Brookman & Jones, 2022; Brown, 1995; Gill et al., 2005; La Vigne et al., 2011). However, a literature on CCTV’s effect on offender apprehension has emerged over the prior decade. Piza et al. (2014b) tested the effect of CCTV on the on-scene apprehension of offenders in Newark, New Jersey. Piza et al. (2014b) found in-progress crime incidents detected and reported by CCTV resulted in an on-scene
enforcement action at a significantly higher rate than crimes reported by citizen calls to the 9-1-1 emergency line (33.1% vs. 17.0%). CCTV’s increased on-scene enforcement rate over 9-1-1 calls was maintained across five of the seven disaggregate crime types included in the analysis: disorder (32.3% vs. 26.8%), drug offenses (44.5% vs. 20.4%), and incidents classified as “other crime” (26.3% vs. 14.4%), “high-priority” (42.2% vs. 8.6%) and “intermediate-priority” (30.6% vs. 18.0%).

A number of additional studies have evaluated the role of CCTV in retroactive police investigations, many of which focused on crime on railway networks. Robb, Coupe, & Ariel (2015) and Sharp (2016) measured the correlation between a range of solvability factors (inclusive of CCTV) on the clearance of metal theft and pickpocketing incidents, respectively, investigated by the British transport Police. While Robb et al. (2015) found CCTV was positively correlated with case clearance, its effect size (measured as standardized mean difference between cleared and uncleared cases) of 0.935 was lower than all but four of the 14 statistically significant solvability factors. Sharp (2016) found 29 of 63 variables exhibited a statistically significant relationship with case closure. CCTV had the third highest effect size. Pickpocketing incidents were 20 times more likely to be solved when CCTV footage was available, as compared to cases without CCTV footage.

Studies using case control quasi-experimental designs have found more positive effects of CCTV on crime clearance in railroad environments. Ashby (2017) found CCTV provided video evidence of crimes occurring on the British railway network in 45% of cases, with

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4 Piza and colleagues (2014) considered both arrests and other enforcement actions (e.g. citations and suspect record checks) in their analysis due to heterogeneous nature of crimes observed on CCTV. While arrest may be the only appropriate response for some serious offenses, police officers have discretion to take a less punitive action in most instances. Results were mostly unchanged when focusing on only arrests or other enforcement. The lone exceptions were arrest rates being significantly higher in the CCTV group for “low-priority” incidents and disorder not achieving statistical significance in the other enforcement analysis.
investigators judging footage as useful in 65% of these cases (which accounted for 29.4% of all cases). Ashby (2017) found having useful CCTV evidence increased the likelihood of case closure from slightly over 20% to approximately 50% (see Figure 3 in Ashby, 2017). Such investigatory benefits were maintained across all crime types except fraud, drug, and weapon offenses, with the largest effects observed for robbery (from 8.9% to 55.7%). Morgan & Dowling (2019) similarly evaluated the effect of CCTV on investigations of crime occurring within a rail network in New South Wales, Australia. They used propensity score matching to create a control group that was statistically equivalent to the CCTV group across five variables (principal offense type, day of the week, time of day, location of the incident, and incident severity). Morgan & Dowling (2019) found clearance rates of cases involving CCTV footage to be 18% higher than the control cases. Effects were particularly strong for property damage and theft/burglary, with CCTV associated with case clearance increases of 64% and 71%, respectively.

A number of recent evaluation studies have measured the investigatory benefits of CCTV within public settings. Similar to the design of Morgan & Dowling (2019), Robin, Peterson, & Lawrence (2021) incorporated propensity score matching to test the effect of CCTV on case clearance in Milwaukee. They found overall case clearances were 14% higher at CCTV-covered intersections than matched control intersections. Crime incidents classified as “Group B” offenses saw case clearances that were 25% higher in CCTV intersections than controls. Petras (2018) tested the effect of CCTV on the clearance of crimes investigated by the Central Connecticut State University Police Department. Correlation coefficients demonstrated CCTV use was moderately associated with both case clearance and the time to case clearance.

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5 Robin and colleagues (2021) classified Group B offenses as minor offenses, such as disorderly conduct, drunkenness, driving under the influence, loitering, and trespassing.
Other studies focusing on public settings have found mixed results. Paine (2012) found CCTV footage being preserved at the crime scene was not significantly related to the clearance of either completed or attempted burglaries in Thames Valley, UK. Jung & Wheeler (2021) found that crime clearance rates significantly increased from the pre- to post-installation period within 500 feet of CCTV camera locations. Changes in clearance rates were insignificant at greater distances. An analysis of disaggregate crime types found theft was the only crime type demonstrating a significant increase in clearance rate within the aforementioned 500-foot CCTV area. Gerell (2021) analyzed the effect of a CCTV system covering deprived neighborhoods in Gothenburg, Sweden. While clearance rates increased for both property crime and violent crime in target areas as compared to controls, neither change achieved statistical significance.

The mixed effect observed across studies is a primary theme in the research on CCTV’s role in case clearance and police investigations. Reasons for this effect heterogeneity are currently unclear. If lessons from research on the crime prevention capacity of CCTV extend to case clearance, we would expect the nature by which CCTV cameras are integrated into daily operations to influence their effect (Piza et al., 2015; 2019). However, attributing the lessons of the CCTV crime prevention literature to case clearance may be premature given the small (but growing) number of studies that have rigorously tested CCTV’s effect on offender apprehension. Future research should prioritize measurement of programmatic and contextual aspects of CCTV that may influence case clearance.

**C. Cost-Effectiveness of CCTV**

Cost-benefit analysis has emerged as a key component of evidence-based crime prevention due to its ability to quantify the fiscal prudence of programs and practices (Welsh, van der Laan, & Hollis, 2013). To the author’s knowledge, three cost-benefit analyses of CCTV interventions
have been conducted to date. It is important to note that these studies considered only the reduction of crime when calculating program benefits. Monetary benefits of case clearance has yet to be quantified in this body of research.

Gill & Spriggs (2005) included a cost-benefit analysis in their national evaluation of 14 CCTV schemes in the United Kingdom. Gill & Spriggs (2005) used estimates generated by Brand & Price (2000) to measure the monetary cost of crime. CCTV intervention inputs were measured from agency documents, with equipment the largest expense accounting for an average of 78% of expenditures across the CCTV schemes. Of the four CCTV schemes to experience a significant crime reduction, two showed evidence of cost-effectiveness, with every £1 spent on CCTV generating £1.24 and £1.27 in savings, respectively. Conversely, the other two schemes were cost prohibitive, with every £1 spent generating only £0.67 and £0.42 in savings, respectively.

La Vigne et al. (2011) conducted cost-benefit analyses of CCTV in Baltimore and Chicago. In both cities, benefits achieved from crime reductions exceeded the upfront and maintenance costs of CCTV, though results were sensitive to how crime costs were calculated. La Vigne and colleagues included both tangible (e.g., government expenditures of the criminal justice system, victim’s lost wages, etc.) and intangible (e.g., fear of crime, pain and suffering, etc.) costs to reflect the full spectrum of victimization. In Chicago, every $1 spent on the CCTV system generated $4.30 in savings when both crime and victim costs were considered, and $2.81 in savings when only crime costs were considered. Lesser cost-savings were observed in Baltimore, with every $1 spent on CCTV generating $1.49 in benefits when both crime and victim costs were considered and $1.06 in savings when only tangible costs were included. The tangible-cost findings reflect, in the words of La Vigne and colleagues (2011, 22), “a more
relevant ratio from a local financing perspective, as any victimization cost savings that might be attributed to the camera system are not transferred to governments’ budgets.”

Piza, Gilchrist, Caplan, Kennedy, & O’Hara (2016) conducted a cost-benefit analysis of the Newark CCTV Directed Patrol Strategy (Piza et al., 2015). They classified intervention costs according to whether they related to the intervention outputs (i.e., the additional CCTV operators, directed patrol officers, and police vehicles) or the preexisting CCTV system (i.e., camera installation, camera maintenance, existing CCTV operators and supervisors). Piza and colleagues (2016) calculated costs of crime two ways: 1) including all tangible societal and criminal justice system costs, and 2) including only criminal justice system costs. Results indicate that every $1 spent on Directed Patrol Strategy outputs generated between $19.36 and $31.62 in savings in light of the achieved crime reduction. Cost-effectiveness reduced when costs of the preexisting CCTV system were accounted for (between $1.63 and $2.04). Overall, the analysis of Piza et al. (2016) suggest that a strategy pairing directed patrol with active CCTV monitoring is cost-effective for agencies with existing (and previously paid for) CCTV systems but may be cost-prohibitive for agencies needing to first invest in CCTV.

A key challenge in interpreting these findings is clearly determining the counterfactual condition. The true value of cost-benefit analysis comes from quantifying the cost-effectiveness of a portfolio of interventions to assist policy makers in determining how to invest limited public resources (Aos, 2015; Welsh & Farrington, 2015). CCTV systems typically cost millions of dollars to install, with maintenance expenses requiring substantial financial commitment on a regular basis (La Vigne et al., 2011). In the spirit of cost-benefit analysis, given that money dedicated towards CCTV could instead be devoted to other programs and practices, it is important to demonstrate CCTV is worth funding over less expensive options (Piza et al., 2016).
However, CCTV researchers are typically unable to determine what alternative programs an agency could have spent money on in lieu of CCTV. As such, analysis findings speak to a CCTV system’s absolute cost-effectiveness rather than its relative cost-effectiveness compared to other policy options. This challenge is exacerbated by the fact that policing and situational crime prevention interventions have incorporated cost-benefit analysis less frequently than other disciplines (Piza et al., 2016). The increased use of cost-benefit analysis in the crime prevention field would allow for more in-depth comparison of the cost-effectiveness of various programs and practices competing for public funding.

III. IMPORTANT KNOWLEDGE GAPS

Despite the development of a robust literature on CCTV, there remain a number of pertinent issues in need of empirical examination. For one, disparities in populations bearing the brunt of surveillance have not received sufficient empirical attention. Harms of CCTV surveillance, in terms of exacerbating racial inequalities, should be balanced against the crime control benefits (Hollis, 2019). This may be accomplished by embracing an expanded research agenda that includes metrics on equal access, equal treatment, and equal impact of CCTV (Hollis, 2019; Piza, Chu, & Welsh, 2022). In considering this issue, it is concerning that CCTV programs have typically been developed absent the type of community involvement that has become increasingly popular in contemporary policing (see e.g. Gimenez-Santana, Caplan, & Kennedy, 2022; Katz & Huff, 2020). Such an approach can be facilitated in CCTV projects through action research frameworks involving active and on-going collaboration between researchers, practitioners, and community stakeholders—such as Community Technology Oversight Boards (Piza et al., 2022).
The CCTV knowledge base on crime control has also stalled in certain respects. While high-quality evaluation studies increased in residential areas (from 2 to 16) and the United States (from 4 to 24) between Welsh & Farrington (2009) and Piza et al. (2019), research has stagnated for certain settings. No new public transport settings met the inclusion criteria for the updated systematic review. Research on the deployment of CCTV in certain countries has also been hindered by weak research designs. We do not know as much as we should about between-country variation in CCTV effect and, by extension, what lessons might be gleaned from examining such variation. While 17 evaluation studies have focused on CCTV in Australia, only one incorporated the type of quasi-experimental method required for inclusion in the systematic review. Evaluation studies from five countries were entirely excluded from the systematic review (Colombia, Germany, Japan, the Netherlands, and Uruguay) due to the universal absence of control conditions (Thomas et al., 2022). Furthermore, while research conducted in the United Kingdom dominated the early CCTV literature, no evaluation studies were conducted in the UK between 2010 and 2016, the final six years covered by the updated systematic review (Thomas et al., 2022). More research is needed to determine whether the positive effects achieved in the UK were maintained over subsequent decades. Comparative work measuring CCTV effect across countries is also important as relevant policies, oversight, legislative restrictions, and normative values can influence variation in the adoption and effect of CCTV across the world.

CCTV has also become a component of a larger apparatus of surveillance technologies, inclusive of license plate readers, linked traffic cameras, and gunshot detection technology (Skogan, 2019). Computer vision and deep learning technologies are also being developed to

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6 However, it should be noted that Priks's (2015) evaluation of CCTV in the Stockholm subway system uses a one-group longitudinal time series design that controls for extraneous factors, which fits the selection criteria of other recent Campbell Collaboration systematic reviews (see e.g., Braga, Weisburd, & Turchan, 2018).
automate the detection of crime-related events, such as a weapon, fugitive vehicle, or aggressive physical behavior (Bhatti, Khan, Aslam, & Fiaz, 2021; Idrees, Shah, & Surette, 2018). Research is needed to test whether and the level to which such a package of technological interventions improves upon stand-alone CCTV systems. Given the developed nature of the CCTV literature, there may be opportunities to use the current knowledge base to inform research and policy development relating to a range of contemporary police technologies (Piza, 2021). Publicly disseminating CCTV research findings for such purposes represents an opportunity to increase research translation (Laub, 2012) within the police technology realm.

More research is needed on issues other than program outcomes, as policymakers need to know more than whether a given practice “works.” Program implementation is a particularly underexplored aspect of evidence-based crime prevention (Sidebottom & Tilley, 2022; Weisburd, Farrington, & Gill, 2017). Implementation issues are problematic in technological interventions such as CCTV, given the variety of interconnected software, hardware, and policy dimensions required for success (Piza et al., 2022; Salvemini et al., 2015). In this vein, CCTV researchers should answer recent calls for evidence-based crime prevention to move beyond focusing solely on crime outcomes in order to generate research findings that provide more practical guidance to policy makers (Sidebottom & Tilley, 2022; Tompson et al., 2021; Weisburd et al., 2017).

IV. CONCLUSION
Should public safety agencies invest in CCTV? The honest answer is “it depends.” While this answer may frustrate practitioners who need to make strategic decisions within a rapidly evolving operational environment—and look to research to help inform such decisions—it is the answer most reflective of the current research evidence.
There are some steps public safety agencies can take to help decide whether CCTV is an appropriate solution in their jurisdiction, and to help maximize the likelihood that CCTV will be effective. CCTV deployment should be preceded by an in-depth analysis of the spatial distribution and nature of crime patterns (Ratcliffe, 2006; Welsh & Farrington, 2002). A public safety agency wishing to combat robbery, for example, is best served by first identifying specific places experiencing disproportionate levels of robbery. Secondly, the specific incidents should be analyzed to identify whether or not the crime activity is susceptible to CCTV. For example, a street corner where a large number of robberies occurs is a more appropriate camera location than the outside of a mall where robberies occur indoors.

Initial problem analyses can be followed by a needs assessment that can determine the appropriate size, scope, and operational mission of CCTV for a given agency (Gill, Rose, Collins, & Hemming, 2006). A rigorous problem analysis may further assist implementation by identifying necessary preparations and support needed to increase the likelihood of success. Criminal justice policies, as well as social policy in general, often face challenges such as inadequate or poor staff training and lack of capacity to track process measures to the level needed to adjust program activities over time (Mears, 2010; Rossi, Lipsey, & Freeman, 2004; Salvemini et al., 2015). Identifying such issues before a program commences can enable the agency to remedy (or at least mediate) specific threats to program implementation.

It is important for the agency to make an honest assessment of the human capital available for surveillance purposes at the outset. Agency policies should also be drafted in a manner that’s supportive of active monitoring practices. Piza et al. (2014b) found the CCTV system in Newark became too large to be efficiently and effectively monitored, with each camera installation phase associated with up to a 47% reduction in weekly surveillance activity. This
was exacerbated by the fact that financial constraints precluded additional personnel being added to surveillance functions in Newark, an issue that has been observed elsewhere (see, e.g., Priks, 2015). CCTV operators in Newark further reported that the Newark Police Department’s differential dispatch policy, which typically resulted in long time frames between incident reporting and officer dispatch, discouraged CCTV operators from reporting crime incidents unless they rose to the level of serious violence. In other words, the Newark PD was not taking advantage of the real-time identification of crime, despite this being an anticipated benefit of CCTV (Piza et al., 2022).

Agencies should also be mindful of a key finding of Piza and colleagues’ (2019) meta-analysis: CCTV schemes incorporating multiple complementary interventions substantially outperformed other schemes. This reflects research finding CCTV effect is heightened when paired with proactive policing strategies (La Vigne et al., 2011; Piza et al., 2015)7 and offender beliefs that CCTV presence does not guarantee increased risk of apprehension (Gannoni et al., 2017; Martin Gill & Loveday, 2003). Police agencies need to ensure their officers have the capacity to quickly address the criminogenic factors identified by CCTV operators. This can be easier said than done given the sometimes overwhelming demands placed on patrol functions by the 9-1-1 call system. However, police can identify whether spatial crime patterns indicate only a subset of cameras warrant additional resources in the form of complementary interventions. In such instances, these cameras could be prioritized for integration with other proactive interventions (Piza et al., 2015). If resource constraints prevent an agency from dedicating additional resources to CCTV operations, agency leadership should commit to installing only the number of cameras

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7 However, it should be noted that Gerell (2016) found a project integrating actively monitored CCTV and foot patrols did not generate any significant effects in Malmö, Sweden.
they can realistically support with proactive monitoring and policing efforts (Piza et al., 2014b, 2015).

Agencies facing such resource constraints (or that prioritize the prevention of violent crime, which CCTV has exhibited less effect on) should frankly consider whether funds would be better allocated toward other crime prevention programs. This is especially so given that the types of proactive activities associated with CCTV effect require a commitment of resources over and beyond what is needed to support stand-alone CCTV camera deployment (Circo & McGarrell, 2021; Piza et al., 2015, 2019). The consideration of alternate strategies is facilitated by the amount of synthesized evidence available on a range of police and situational crime prevention interventions (Piza & Welsh, 2022; Welsh, 2019). When considering the cumulative findings of the CCTV cost-benefit research, CCTV schemes often fail to deliver sufficient crime reduction benefits to offset the costs of installing and operating the system (Gill & Spriggs, 2005; La Vigne et al., 2011; Piza et al., 2016). Even studies finding monetary benefits likely do not speak to the true monetary cost benefits public safety agencies can expect, mainly because cost estimates typically include intangible societal costs. As argued by Ratcliffe (2015) "monetary costs to society mean little to the police as they do not recoup the costs of any crime reduction directly."

In considering operational efficiency, it is crucial that agencies remain mindful of social equity. Actively soliciting the input of community organizations can be invaluable. The City of Newark partnered with the local chapter of the American Civil Liberties Union (ACLU) when planning its CCTV program to ensure technological protections, such as ensuring the video monitoring software automatically blacked-out all windows and other views into private spaces (Piza et al., 2022). Written policies should also clearly outline legal requirements for reasonable
suspicion and probable cause. Prior research has documented CCTV operators relying on extra-legal factors to select individuals for surveillance (Loveday & Gill, 2004; Norris & McCahill, 2006) and engaging in inappropriate (e.g. commenting on the attractiveness of women involved in domestic disputes) (Norris & Armstrong, 1999) or illegitimate (e.g. watching television) (Gill et al., 2005) surveillance activities. In this sense, the success of CCTV may be influenced by nontechnological factors, such as written policy, training, and performance oversight.
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