Flock Safety Technologies in Law Enforcement: An Initial Evaluation of Effectiveness in Aiding Police in Real-World Crime Clearance

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Abstract. A growing number of law enforcement organizations are using and integrating Flock Safety technologies, specifically automated license plate readers (ALPRs), to enhance their crime control functions. While these technologies have significantly improved through development, their effectiveness in real-world usage requires evaluation. This study analyzes data collected by a representative sample of small, medium, and large agencies that use Flock technologies to measure the impact of Flock ALPR using regression analysis that measures product variables with public Uniform Crime Report data. Initial findings suggest a positive impact of Flock technologies on clearance rates. This warrants further examination of the impact of Flock technologies on specific crime types and statistical comparisons before and after these technologies were implemented.

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Introduction

This paper attempts to quantify and fill an existent knowledge gap surrounding the efficacy of automated license plate reader (ALPR) cameras for law enforcement. In recent years, the conversation surrounding ALPR has shifted from "Do they help solve crime?" to "How do they solve crime, and how much?" This trend largely parallels ALPRs' product maturation and greater real-world usage by law enforcement agencies. Whereas older studies noted prohibitive cost (Dobbs 2014), recurrent technical issues (Lum et al 2010 65), and small deployment sizes (Koper et al 2012 41) as blockers to effective ALPR performance, studies conducted after ALPR cameras rapidly became more performant, more cost-effective, and more seamlessly embedded in law enforcement workflows have demonstrated statistically significant law enforcement outcomes. More recent studies have found that the use of ALPR can be attributed to increases in follow-up arrests (Ozer 2016 124), to identifying more stolen vehicles and making more arrests as a result (Potts 2018 15), to improvements in case closure rates for both auto theft and robbery in areas of high-density ALPR deployment (Koper and Lum 2019 320), and towards generally improved traffic safety (Zmud et al 2021 33).

Nonetheless, existent research on ALPR effectiveness typically does not attribute crime clearances to ALPRs directly, with case studies relying upon retrospective attribution based on case clearances over time or comparing ALPR-equipped groups with non-ALPR-equipped groups. Further, existing research relies either upon handfuls of anecdotal interviews with ALPR-equipped law enforcement agencies or deep dives into the ALPR use data of a single city, agency, or even a subset of officers within an agency at a time.

Methods of Inquiry

In this paper, we consider the most expansive and tightly attributed survey of ALPR crime clearance data to date in order to deepen our understanding of what leads a law enforcement agency to solve more or less crime with ALPRs. This dataset was sourced from a survey of Flock Safety ALPR customers conducted from April to June of 2023. Though this data must be presented in an aggregated form as a condition of its collection,[1] we explain the collection process and data validation in detail.

From there, we combine agency-attributed ALPR crime clearances with historical FBI-reported crime data to calculate the portion of crime solved within each of the law enforcement jurisdictions with data of sufficient quality for inclusion. We then use those clearance rates as the dependent variable in a statistical model that finds a line of best fit for how much crime a theoretical "typical" agency would solve with Flock Safety ALPR cameras given their use of Flock Safety's cameras and software products, the agency's resources independent of their ALPR cameras, and relevant socioeconomic factors for the agency's jurisdiction based on the real data for the reporting agencies. The factors extrinsic to the ALPR data were selected following the FBI's best practices for comparing law enforcement agency outcomes. We explored several appropriate modeling techniques, searching for the framework that produced the highest combined correlation coefficient to our dataset.

In our analysis, we isolate the relative impact of ALPR-centric, agency-centric, and jurisdiction-centric factors upon ALPR-assisted crime clearances. Acknowledging the broad, general conclusions of this preliminary, exploratory study, we conclude by noting the additional

[1] Law enforcement agencies were understandably concerned about potential subsequent disseminations of line-by-line, case-by-case information from their jurisdictions. Because this study was always intended to be a broad survey of Flock-assisted closures that would not require delving more deeply into crime types or seasonality, we made the concession only to present aggregated data early on to maximize our response rate.

avenues for more targeted research via statistical tests coupled with in-depth qualitative data that this general model suggests.

Data Collection and Validation

Part one: Raw numbers of crimes solved

Respecting how complicated it is to attribute crime clearances to a single technology amidst so many potential factors, the request was simple: “How many arrests have you made that can directly be attributed to the use of a Flock Safety camera?” Respondents were asked for the corresponding case records, which we then audited individually to ensure that attributions were clear and that they were only for offenses reported to the FBI, filtering out reports of clearances for minor traffic offenses, stolen vehicles recovered without an arrest, and instances where it was otherwise unclear what the referent of a report was.

As a whole, the survey responses faced the same challenges noted by Zmud et al in 2021 talking with individual agencies: consistently capturing this kind of data is very difficult, and practices are in no way standardized across different ALPR-equipped agencies. Some records came from records management systems (RMS); some from Flock Safety’s reporting tool that allows agencies to track ALPR outcomes; some were tracked manually in Microsoft Excel or Google Sheets. While some agencies using an RMS had clear, easily identifiable designations for ALPR-assisted clearances, it was often the case that ALPR assistance was identified only in unstructured text in the “Notes" section of an RMS, necessitating careful searches by analysts to identify exhaustively the ALPR-assisted clearances. The opposite problem was the case with records kept by hand in a spreadsheet tool–though it was clear in this case that Flock assisted

with the crime in question, it often required very careful auditing to ensure that the clearance was for a crime reported to the FBI and not for a minor traffic offense.

We controlled for the imperfect data records by requesting records from a very high number of law enforcement agencies. Of the customers surveyed, we received 477 replies; of those replies, 246 replies provided data; of those 246 data points, 195 provided sufficient granularity surrounding clearance data to warrant further investigation.

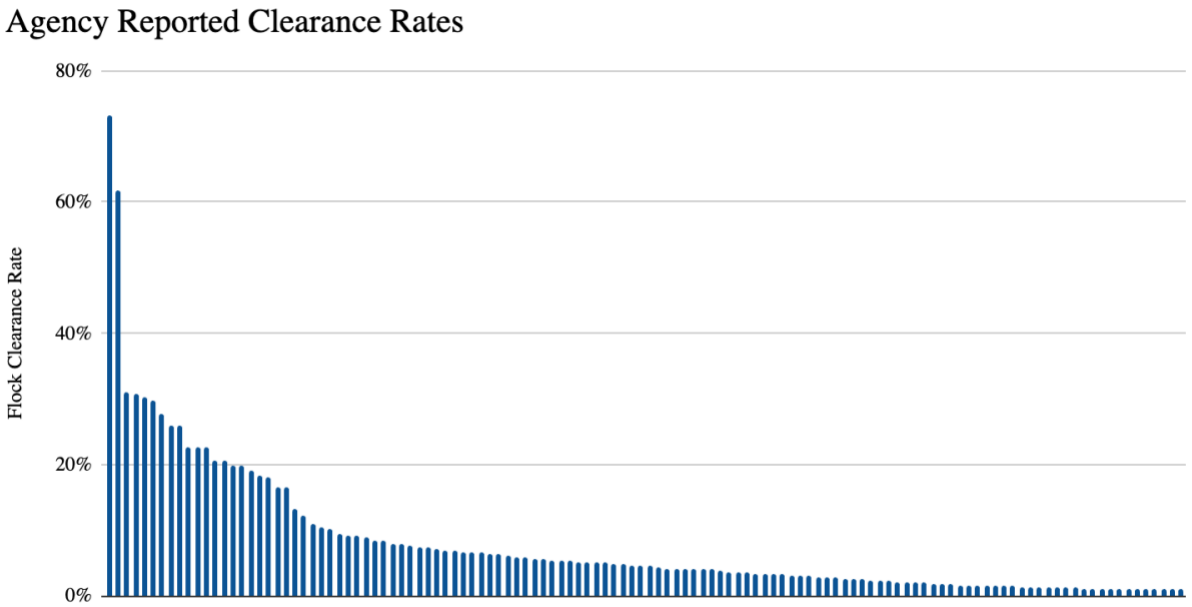
Part two: Overall percentage of crimes cleared

The reporting agencies varied widely in the overall crime rate within their jurisdictions. With this in mind, we sought next to standardize the raw number of reported crimes solved with Flock Safety ALPRs. Determining how much of the overall crime in an agency's jurisdiction those clearances represented, we then approximated a "Flock-assisted clearance rate".

To ensure a consistent reporting framework for overall crime, we opted to use the overall crime data reported by survey respondents to the FBI's Uniform Crime Reporting (UCR) program. To use the latest data while accounting for the unusual 2020-2021 period in crime statistics, we used the average number of crimes for each year the agency reported to the FBI since 2016 as our denominator. Not every agency uses the FBI UCR system, and non-reporting agencies were thus excluded from subsequent analysis.

Implausible outliers on both the low and high ends emerged from dividing this numerator–the number of Flock-attributed arrests in the survey–and this denominator–the average crimes reported to the FBI from 2016-2021. On the low end, it emerged via follow-up conversations with respondents that exceptionally large jurisdictions often simply were not equipped to report comprehensively on Flock-assisted clearances. On the high end, additional scrutiny of the FBI-reported crime statistics revealed wide fluctuations in the reporting years that

led to artificially low averages. Both classes of outliers were excluded from subsequent analysis. Below is a distribution of Flock ALPR-assisted clearance rates.



Data Analysis

Part one: Flock-internal and Flock-external factors considered

Two additional data sets were used beyond the survey responses and the UCR data: the reporting agency's internal data with Flock Safety, and the most recent census data for their jurisdiction.

The former consisted of the following metrics throughout the reporting period: how many cameras the agency owned; the median ALPR cloud data upload speeds; how often cameras experienced high, medium, and low impact service issues; how often officers at the reporting agency used Flock Safety's software tools; how many additional ALPR cameras the agency had access to via inter-agency sharing and community-owned cameras; and how many other Flock

Safety customers were within 50 kilometers of the agency's jurisdiction. This data was sourced from Flock Safety's cloud data warehouse for the time period corresponding to the survey respondent's reporting period.

Census data was acquired via the application programming interface on the census website using Flock Safety's internal mappings of law enforcement agency jurisdictions to census subdivisions. Factors to consider were drawn from the FBI's cautionary best practices on ranking law enforcement agency effectiveness (https://ucr.fbi.gov/ucr-statistics-their-proper-use) and included the following categories and specific metrics: population density; economic prosperity (percentage of persons in poverty, median household income); urbanization (commuter statistics, population delta between 2010 and 2020, number of traffic intersections, and, again, population density); youth concentration and family makeup (persons per household, median age). Population statistics were also collated with the reported number of sworn officers for each jurisdiction's originating agency identifier to determine relative law enforcement resources for each responding organization.

The table below describes the individual metrics in greater detail.

Independent Variable	**Definition**
Device Penetration	
Number of Flock Devices	Number of Flock devices owned by customer
Active Device Days	The sum of the number of days each customer-owned device was active
Devices per Sworn Officer	The number of devices normalized by the number of sworn officers recorded by the FBI based on the agency ORI number
Devices per Population Serviced	Number of devices normalized by the size of the population served. Collated with US Census data based on the county subdivision associated with the agency ORI
Product Performance	
Median ALPR cloud data upload speed	Median time in seconds between an image being captured by a Flock Safety ALPR camera and an alert being sent to end users
90th Percentile ALPR cloud upload speed	90th percentile time in seconds between an image being captured by a Flock Safety ALPR camera and an alert being sent to end users
Percentage of days with service issues	Separated into days with only high-impact issues, days with high and medium-impact issues, and days with any (high, medium, or low) impact issues.
Product Adoption	
Agency Monthly Product Adoption	Percentage of registered users at the reporting agency who logged into any part of Flock Safety's software

Agency Monthly Hot List Adoption	Percentage of registered users at the reporting agency who logged into the Hot List (i.e. alerting) component of Flock Safety's software
Agency Monthly Search Adoption	Percentage of registered users at the reporting agency who logged into the Search (i.e. investigations) component of Flock Safety's software
Network Effects	
Percentage of cameras in state accessible	Total number of Flock Safety cameras customer has access to within the state via network sharing divided by the total number of Flock Safety cameras within the state.
Shared Devices per Sworn Officer	The number of Flock Safety cameras customer has access to normalized by the number of sworn officers recorded by the FBI based on the agency ORI number
Number of Nearby Flock Customers	Number of Flock Safety customers within a 50 km radius of that customer
External Factors	
Population Change Percentage	Percentage change in population served by the agency as measured by the change in population from the 2010 US Census to the 2020 US Census
Median Income	Median income of the population served by the agency as reported by the US Census
Poverty Rate	Percentage of families within the agency's jurisdiction below census-determined income thresholds as reported by the US Census
Persons per Sworn Officer	Size of the population served by the agency as reported by the US census normalized by the number of sworn officers reported by the FBI
Persons per Household	The average number of persons per household of the population served by the agency as reported by the US Census
Persons per Square Mile	Population density of the population served by the agency as reported by the US Census
Median Age	Median age of the population served by the agency as reported by the US Census

Because of the number of factors under consideration and the size of the dataset, there were instances where individual metrics were missing for some respondents. As one example, because of the novel mapping between respondents and census subdivisions, there were instances where it was impossible to acquire the 2010 population of shifting census subdivisions, and it was thus impossible to determine the population delta between 2010 and 2020 for a reporting agency's jurisdiction. As another, certain reporting periods occurred during periods of transition for Flock Safety's internal reporting of platform use and device sharing. In such instances where a data point was missing only an internal metric or an external metric, either the mean or median value for the metric was used as an imputed value as statistically appropriate. Instances where multiple internal or multiple external metrics were unavailable or both an internal metric and an external metric were unavailable were excluded from the analysis.

This left a final total of 123 values under consideration; the next section details how we subsequently pared down the factors described in this section to an appropriate number of independent variables for this sample size. The agencies included in the data represented a wide range of agency types and jurisdictions served. Below are some details on the demographics of the agencies included in the analysis.

Table 1

Distribution of Agency by Size

Sworn Officers	# of Agencies
1-25	15
26-50	24
51-75	14
76-100	15
101-250	36
251-500	9
501-1,000	6
>1,000	3

Table 2

Distribution of Agencies by Population Served

Population	# of Agencies
<25,000	33
25,001 – 50,000	17
50,001 – 100,000	18
100,001 – 250,000	25
250,001 – 500,000	15
500,001 – 750,000	4
750,000 – 1,000,000	2
>1,000,000	8

Table 3

Distribution of Agencies by Population Median Income

Median	# of Agencies
<$40,000	7
$40,001 - $50,000	17
$50,001 – $60,000	18
$60,001 – $70,000	28
$70,001 – $80,000	14
$80,001 – $90,000	10
$90,001 – $100,000	12
>$100,000	16

Part two: Regression Analysis

With a refined dataset of ALPR-centric factors and agency demographic factors, we sought to determine which set of factors were most associated with agency clearance rates. We pursued several methods of regression analysis to determine the best independent variables.

Single Regression Analysis

First, to determine the individual variables that had the greatest correlation with ALPR-assisted clearance rate, we began our analysis by running individual linear regressions with the

percentage of crime cleared with ALPR cameras as the dependent variable for each independent factor described above. This was performed as an intermediary step toward our desired holistic model by identifying the most significant individual variables before working to understand how those variables interrelate.

Broadly and unsurprisingly, the ALPR-centric factors had greater correlations with crime cleared via ALPR cameras than demographic or jurisdictional factors. Notable exceptions were population density and persons per sworn officer. These factors were correlated with ALPR-assisted clearance rate more strongly than external factors more intuitively relevant to ALPR cameras–particularly the number of traffic intersections within jurisdiction–as well as hardware device performance metrics surrounding cloud upload latency and percentage of days with service issues.

We speculate these external factors were especially predictive because of how fundamental and multifarious they are. Population density is a proxy for, among other things, urbanization, economic conditions, and modes of transportation within an area. Persons per sworn officer is a measure not only of the relative resources of the agencies themselves but also the cultural and economic factors that lead an agency to have greater or fewer resources. Regarding the lack of explanatory power for cloud upload latency and days with service issues, it is worth noting that the datasets surrounding these metrics had relatively low cardinality, perhaps creating outsized noise relative to the diversity of the reported clearance rates.

Multivariable Regression Analysis and Optimization

Pruning the low-correlation independent variables, we iterated through a multivariable regression of every permutation of remaining variables to identify the model that best explained the variance amongst clearance rates while keeping to two constraints: that only six factors be

chosen, and that the factors be as conceptually distinct as possible. The former was done out of necessity based on the size of our dataset. There were simply too many potential factors to model holistically without generating an over-fitted model for our multilinear regression, as best practices of only including a feature for roughly every twenty inputs for this type of model would restrict us to six features.

Towards the latter, we partitioned the remaining individual Flock-internal factors into four categories (with two of our six dependent variables devoted to population density and population per sworn officer): Flock Safety software adoption rate, the density of Flock Safety hardware products in jurisdiction, Flock Safety camera network sharing participation rate, and Flock Safety market maturity. Running through the permutations, the most significant variables for each category were the peak number of cameras owned during the reporting period per sworn officer, the adoption of the Flock Safety hotlist tool throughout the reporting period,[2] the number of Flock Safety cameras owned by other law enforcement agencies and private entities shared with the jurisdiction during the reporting period, and the number of Flock Safety customers within 50 kilometers of the reporting jurisdiction.[3]

[2] This portion of the Flock Safety platform automatically collates ALPR reads with official databases of plates associated with criminal activity, as well as an agency's custom lists of plates with known investigative relevance, to deliver real-time alerts for when suspect vehicles pass an ALPR camera.

That this was the single portion of the Flock Safety platform whose adoption correlated most strongly with increased ALPR-assisted clearance rates is continuous with Zmud et al 2021, 3, where "linking the ALPR system to the State's crime information computer" and "having close coordination with the external steward of the hot lists" are two of the four recommendations by ALPR-equipped law enforcement personnel for success with ALPR technology.

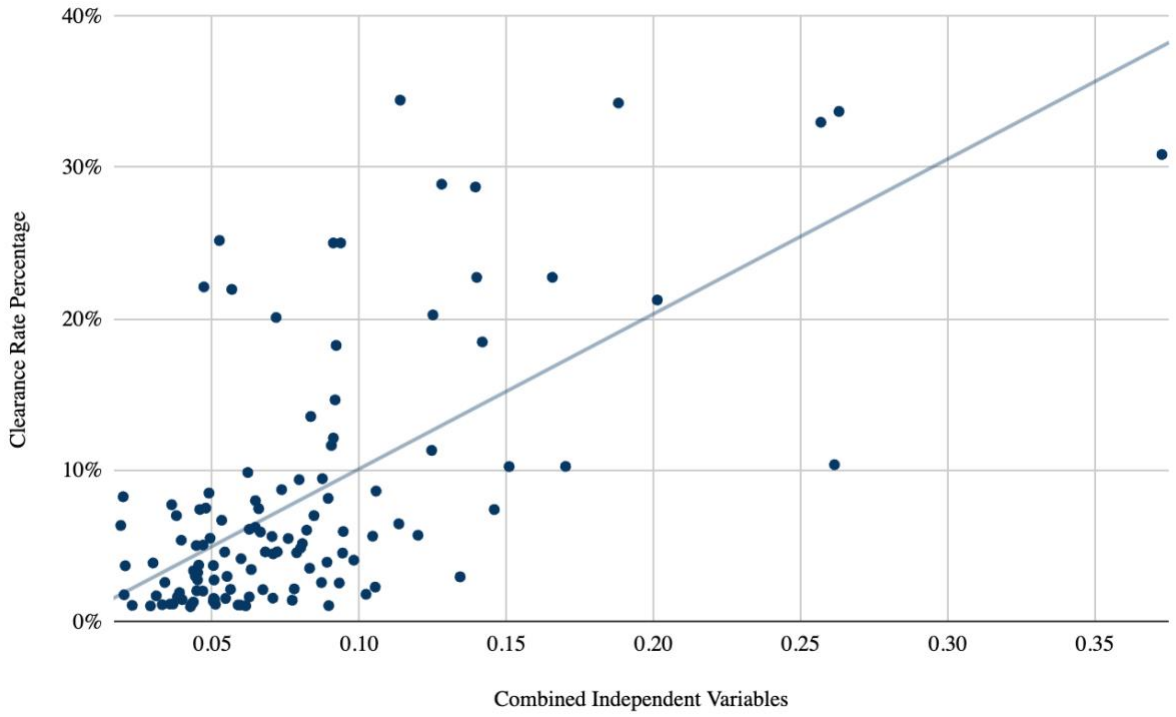
[3] One assumption of this model grounded in empirical reality rather than pure statistics should be noted. Because a theoretical jurisdiction not only with no ALPR camera use, no ALPR camera-related software use, and no other nearby ALPR customers, but also no law enforcement officers and no population for those zero officers to serve would not only solve no crime with ALPR cameras, but have no crime at all–because it would not exist–we enforced that our multilinear regression model pass through the origin, with a confluence of zero for all the independent variables reasonably translating to a zero ALPR-assisted crime clearance rate. We note as well the dismissal of one exceptional submission–an agency that still appeared to clear nearly 80% of the crime in its jurisdiction with ALPR assistance after all further scrutiny–from the final data set due to the model otherwise overfitting to it.

In addition to considering different independent variables, we also considered different regression techniques. In each permutation of variables, we analyzed the data using a Multivariate Ordinary Least Squares (OLS) regression, Least Angle Regression (LARS), Ridge Regression, and Random Forest Regressor. With our constraints in mind, we selected the independent variables and modeling technique that had the highest correlation coefficient to our dataset.

Results and Findings

We found that a multivariate OLS regression had the highest correlation to our data set with an R-squared of 0.69. The six independent variables were Flock Devices per Sworn Officer, Agency Monthly Hotlist Adoption, Shared Flock Devices per Sworn, Number of Nearby Flock Customers, Persons per Square Mile, and Persons per Sworn Officer. Summing all of the independent variables and their coefficients, we can plot the relationship between these six factors and agency clearance rate based on the data submitted by agencies.

Multilinear Regression



$$Clearance\ Rate\ \% = 9.1 \times Flock\ Devices\ per\ Sworn + 5.3 \times Agency\ Monthly\ Hotlist\ Adoption + 0.0083 \times Shared\ Flock\ Devices\ per\ Sworn + 0.050 \times Number\ of\ Nearby\ Flock\ Customers + 0.00013 \times Persons\ per\ Sworn - .00025 \times Persons\ per\ Square\ Mile$$

This analysis shows a clear relationship between how an agency uses Flock technology and the results they achieve. There are four themes that emerge.

Access to Evidence

Intuitively, both Flock Devices per Sworn and Shared Flock Devices per Sworn have positive coefficients with clearance rate. This indicates that an agency of a given size can increase their likelihood of solving crime with access to additional devices that capture evidence, whether that be by purchasing additional devices or requesting access to additional devices owned by other agencies and private entities.

We can explain the Shared Devices per Sworn coefficient being relatively low via the fact that a typical agency that works with Flock will have access to more than 200 times the number of cameras that they own via sharing. Simply, it takes significantly more cameras being shared with the agency to have the same impact as the agency owning more cameras. Quantifying the impact of the latter using this framework, a typical agency that acquires an additional owned Flock Device per Sworn Officer may expect a 9.1% increase in ALPR-assisted clearance rate.

Agency Behavior

While some agencies constrain access to ALPR technology to select officers, the positive coefficient between Flock hotlist software use and crime clearance suggests that an agency that provides access more broadly to ALPR-related software will be more successful in solving crime. Much of an agency's success in locating and apprehending suspects is done by officers in the field, and Flock's software is accessible to field officers via a mobile data terminal (MDT) or the Flock mobile app. We believe widespread agency use of Flock should be paired with a high degree of control over user-level permissions and auditing to ensure proper use, both of which are a core piece of Flock's technology.

Collaboration with Other Flock Users

There appears to be an additional positive correlation at the local level for collaboration between Flock customers beyond what is explained by the nationwide ability for customers to share with each other. The median number of cameras granted access to in a given camera-sharing interaction is ten, and the median sworn officer count amongst respondents was 34, meaning that an agency will need to gain access to roughly 3.5 additional typical Flock customers' cameras to drive their Flock-assisted clearance rate up by .0083%.

This is markedly lower than the additional .05% increase in clearance an agency can expect simply for having another Flock customer–regardless of market segment–within 50 kilometers of them. Considering the coefficient for Nearby Customers, if 20 additional customers begin working with Flock in a community, Law Enforcement can expect a 1% higher Flock-assisted clearance rate.

Data Collection for Large Agencies Remains a Challenge

It is striking that the model predicts a higher clearance rate for agencies with fewer sworn officers relative to the size of their population as well as for agencies that have a population distributed over a larger area. These findings may make sense when considering how ALPR technology can augment the effectiveness of Law Enforcement human efforts. An agency that is tasked with protecting a large area with fewer resources will be more likely to rely on Flock devices that are active 24/7, regardless of when officers are on patrol.

It is also possible that these findings are a product of agencies from very large jurisdictions disproportionately being filtered out due to data quality issues. It may be the case that our model biases towards smaller jurisdictions with more persons per sworn officer not because large agencies solve less crime with ALPR cameras, but because it is much more

difficult for large agencies to track their results comprehensively. This gap in our model invites subsequent research targeted at larger agencies.

Avenues for further research

This study was intended as an initial exploration into a gap in our current understanding of ALPR technology's use by and efficacy for law enforcement. By using an unprecedentedly broad survey of ALPR-equipped law enforcement practitioners that clearly attributes crime clearances to ALPR devices, we have identified general potential root causes associated with higher rates of ALPR-assisted crime clearances. As a general survey of crime clearances post-installation, there are several future studies that suggest themselves immediately.

For one, it would be worthwhile to measure the relative effectiveness of ALPRs in solving different types of crime. It makes intuitive sense that ALPR cameras would likely be more effective at solving crimes directly related to motor vehicles or where motor vehicles are disproportionately likely to be involved. The most obvious category would be motor vehicle theft itself.

However, delving into individual crime types requires methodological considerations particular to the type of crime considered. A study on motor vehicle theft and ALPR-assisted law enforcement outcomes would need to be attentive to the exceptionally low clearance rate for motor vehicle thefts owing to the fact that a motor vehicle theft is only considered cleared for ORI reporting purposes if an arrest is made–a criterion that is inattentive to the common scenario in which a stolen vehicle is spotted on an ALPR camera and then recovered unattended shortly afterward.

There is also a significant underlying causal inference to be tested in light of our findings: having established how much crime has been solved with the assistance of ALPR devices at

these agencies, it must be established that these are crimes that otherwise would have remained unsolved in the first place. Given the state of data collection on this issue, it is unlikely to be solved at scale via quantitative analysis. A mixed-methods study that considers both the qualitative change in practice, workflow, and results at a handful of agencies known to have adopted ALPR technologies and the quantitative, before-and-after impacts of those changes would better capture the day-to-day efficacy of this technology not reflected in the top level metrics considered here. Such a study is presently underway as part of a joint research project by Texas Christian University and the University of Texas at Tyler.

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