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Automatic licence plate reader (ALPR) technology: Is ALPR a smart choice in policing?

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Abstract
ALPR systems have been rapidly spreading in the US. However, little is known about their effectiveness. Results of an interrupted time series model suggest that ALPR systems significantly increased follow-up arrests in the Cincinnati Police Department (CPD) compared with traditional policing approaches. Human resources cost analysis of the study showed that ALPR technology carried out more follow-up arrests by using fewer police officers compared with traditional policing. Finally, cost-effective analysis revealed that ALPR technology is cost-effective and amortises itself within less than one week for property crimes, and less than a month for violent crimes.

Keywords
ALPR technology, cost-effective analysis

Introduction

In recent years, many police departments have adapted automatic licence plate reader (ALPR) systems to accomplish multiple law enforcement purposes, including: traffic enforcement, parking management, tollbooth operations, secure area access control, collection of delinquent taxes and fines, homeland security and terrorist interdiction, America's Missing: Broadcasting Emergency Response (AMBER) alerts, gang and narcotic interdiction, the identification of suspended and revoked drivers, and the recovery of stolen vehicles (ELSAGNA, n.d.). One of the fastest-growing applications of ALPR systems in police agencies across the United States is in the identification of

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vehicles whose licence plates are involved in some type of criminal activity (ELSAGNA n.d.). It is estimated that as much as 70% of all perpetrated crime involves the use of a vehicle (ELSAGNA, n.d.). In this sense, targeting licence plate numbers gives police departments a substantial opportunity to capture criminals and to control future-related crimes.

The use of ALPR systems, however, is still in its infancy in policing, and empirical studies of the effectiveness of this technology are very limited, particularly studies of its use in the United States. Given this context, the aim of this study is twofold. The first is to introduce ALPR systems in policing: how it works, average cost and the empirical status of ALPR systems. Second is to evaluate ALPR systems in terms of its cost-effectiveness by using Cincinnati Police Department data.

ALPR systems in policing

Through its illuminated (infrared) camera, the ALPR system first captures a licence plate photo and identifies the licence plate number, which comes in a variety of forms (i.e. different state licence plate numbers, letters, characters and colours). Then the optical character recognition (OCR) engine reviews the images identified by the ALPR processor and converts the best images to text strings. Finally, the converted text string (licence plate number) and image of the vehicle are presented in the application software (Federal Signal Public Safety Systems, 2008). After this process, the information obtained (the text string) is compared with law enforcement databases containing pre-identified licence plate numbers of vehicles known to be or suspected of being involved in criminal activity. If the sent information matches an entry in an included database, an alert appears on the police officer's computer or at a command centre (if the scan came from a fixed ALPR site) that a suspect or 'hit vehicle' is in close proximity to the ALPR system (Chen *et al*., 2006; ELSAGNA, n.d.; Manson, 2006).[1] The traditional method for police officers to conduct licence plate checks involves an officer entering the licence plate number of a suspicious vehicle into a mobile data terminal to learn the status of the vehicle. Using this method, an officer can check approximately 150 vehicles during a typical shift (Manson, 2006). In contrast, ALPR technology allows for the automatic scanning of up to 3,600 vehicles during the same time period (Combs *et al*., 2009; ELSAGNA, n.d.).

Applying ALPR technology to daily police activities requires significant financial investment. The cost of a single ALPR mobile unit (mounted in a police patrol vehicle) is approximately $20,000; fixed or site ALPR units (mounted to stationary structures like bridges) are even more expensive (approximately $100,000). Despite the high cost of ALPR systems, many police departments have made the investment of scarce resources in this technology because it is believed easily to increase their data-driven policing capability (Gaumont, 2009). Indeed, police departments in all 50 states have installed or are installing ALPR systems (ELSAGNA, n.d.).

Even though implementation of ALPR systems in daily police work has been rapidly increasing, empirical studies of the effectiveness of this technology are very limited. Anecdotally, most police departments using ALPR report increases in efficacy associated with its implementation. Furthermore, the few empirical studies on this topic indicate preliminary success of this technology, improving public safety and increasing effectiveness (Russell, 2009). For example, British police forces evaluated ALPR technology for 13 months in 2002. Within this time frame, the team using ALPR stopped 180,543 vehicles. From these stops, officers:

- arrested 13,499 persons, including:
  - 2,263 arrests for theft and burglary
  - 3,324 arrests for driving offences (for example driving whilst disqualified)
  - 1,107 arrests for drugs offences
  - 1,386 arrests for auto crime (theft from and of vehicles); and

- recovered or seized property, including:
  - 1,152 stolen vehicles (valued at over £7.5 million)
  - 266 offensive weapons and 13 firearms
  - drugs worth over £380,000 from 740 vehicles
  - stolen goods worth over £640,000 from 430 vehicles (Watson and Walsh, 2008: 5).

Using ALPR technology, the British police forces increased their number of arrests 10 times compared with the national average arrest rate (Watson and Walsh, 2008).

Other studies indicate the evaluation of ALPR systems can vary based on certain factors, such as the type of crime. Specifically, the Royal Canadian Mounted Police (RCMP) used the ALPR systems to focus on an increase in the number of auto thefts in 2006. The analysis of ALPR data, however, indicated that ALPR patrol vehicles only identified 1% of stolen vehicles during the period from 10–31 October 2006. The reason for this low identification rate is that the licence plate numbers of stolen vehicles are often altered or the vehicle is left unattended after the commission of the crime (Gaumont, 2009). Therefore, the evaluation of ALPR systems in terms of reducing and preventing crime may vary based on different types of crime.

In the current study, the evaluation of ALPR technology is straightforward: using Cincinnati Police Department (CPD) data, the number of arrests before and after the implementation of ALPR system will be compared in order to find out the value of ALPR technology to the police department. After this comparison, the researchers will be able to conduct a cost-effectiveness analysis based on the findings from the pre-post arrest comparison.

Methodology

Data for this study come from several different databases of Cincinnati Police Department (CPD).

ALPR data

ALPR data come from the ALPR Unit of the CPD from 16 July 2008 to 15 July 2009.[2] For the current study, only data collected by the eight ALPR patrol vehicles deployed in the City of Cincinnati are utilised. ALPR units deployed in Hamilton County and Green Township are under the direction of different police agencies, and these geographic areas do not have city shape files available, which are necessary for ArcGIS mapping software. Therefore this study includes 2,823,944 scanned licence plate numbers, based on only the ALPR data provided by vehicles serving the City of Cincinnati from July 2008 to July 2009.

The ALPR database contains entries for the following data fields: ALPR scan date and time, officer login name, geographic coordinates, control numbers for identified criminals, the scanned vehicle's driver involved crime type, demographic characteristics of the scanned vehicle's driver (e.g. date of birth, height, weight, eye colour and hair colour), reason for ALPR stop and police action as a result of traffic stop (i.e. felony arrest, issuing a ticket).

Incident data

Incident-level crime data are also provided by the CPD. The incident-level crime database includes information related to violent crime and property crimes. In addition, the database indicates whether the police classify the incident as 'closed' (i.e. an arrest has been made) or whether the investigation is still pending (i.e. identification or investigation of perpetrators is still ongoing).

Arrest data

Arrest data provided by the CPD include 2008 and 2009 violent crime and property crime criminal arrests. The database provides detailed information about arrestees, such as race, gender, home address, control number for identification purposes, incident number, incident address, incident date and time.

Closure by arrest data

The CPD also provided its closure by arrest database, which differs from the other arrest database in that it only contains follow-up arrestees (i.e. arrests resulting from incidents classified as 'investigation pending'). When the perpetrator of an incident still under investigation is arrested by the police, this type of incident is marked as 'closed by follow-up arrest'. This database includes follow-up arrest records from 2006 to 2009 and includes incident number, incident type, race, gender, and clearance/closure type (i.e. arrest adult, warrant issued).

Analytical plan

In order to test the impact of ALPR systems on the number of follow-up arrests made by the CPD, a comparison will be made between the number of monthly follow-up arrests[3] before and after the CPD's implementations of ALPR technology in July 2008. Because the unit of analysis for this test is time (e.g. months), interrupted time series analysis will be used. Specifically, the time-series analysis will compare the number of arrests per month for a three-year period prior to the implementation of ALPR (2006–2008) with the last year's number of arrests (2008–2009) to examine whether statistically significant differences in the number of arrests are evident. Regression analysis for time series is not an appropriate model because time points that are close to each other are generally highly correlated. For this reason, error terms cannot be assumed as random, which is a clear violation of regression models. To overcome this correlated error problem, different time series analyses were developed to clean correlated error and leave the random component of error terms (Box and Jenkins, 1976). Auto regressive integrated moving average (ARIMA) models, available in SPSS 17, are one of these time series analyses and are generally used to predict the effectiveness of an intervention time point. For cost-effectiveness analysis, simple comparison techniques such as two sample t-test will be used.

Measure of variables

Dependent variable-1

There are two dependent variables of interest for this study. For the first comparison, the dependent variable is the 'number of follow-up arrests per month'. As previously noted, ALPR mobile units randomly patrol in the city and seek for pre-identified criminal vehicles. In other words, ALPR mobile units look for criminal drivers who were not arrested during an incident and sought by the police after the incident. Likewise, the Cincinnati Police Department has a database that contains follow-up arrestees who were not arrested during the incident but were arrested after conducting follow-up investigations. For instance, the suspect of a domestic violence call may not be present at the time of incident, but detectives might have arrested that person after conducting a follow-up investigation. Since follow-up arrest procedure is very similar to the arrest process of ALPR systems, we selected the number of follow-up arrests as the dependent variable to obtain a fair comparison tool for the number of ALPR hits.

In this context, the monthly number of follow-up arrests beginning from January 2006 to July 2009 were included for this analysis ($n = 42$ months). Because the ALPR technology was fully implemented in July 2008, monthly follow-up arrests from July 2008 to July 2009 reflect the sum of ALPR follow-up arrests and traditional policing follow-up arrests. This study hypothesises that ALPR mobile units increased the number of follow-up arrests in the City of Cincinnati after the implementation of ALPR mobile systems.

Dependent variable-2

Even though the second dependent variable looks like similar to the first dependent variable, its measurement process is different. With the second dependent variable, the researchers aimed to capture the average number of follow-up arrests made by the ALPR technology and traditional policing. In this way, the average number of follow-up arrests for the periods of 1 January 2006 – 31 December 2008 made by traditional policing units can be compared with the number of ALPR arrests for the period of 16 July 2008 – 15 July 2009 made by ALPR units. Three-year average for traditional policing will be used because averaging minimises random fluctuations in monthly follow-up arrests. This study hypothesises that ALPR mobile units made more follow-up arrests with fewer human resources.

Independent variables

Follow-up arrests. The first independent variable for the comparison of the number of follow-up arrests before and after the implementation of ALPR technology is a dichotomous variable (the number of follow-up arrests done by ALPR units = 1 and the number of follow-up arrests by non-ALPR units = 0). With the term of time series analysis (1) describes intervention time points and (0) represents the others. The second independent variable is the number of pending investigations for 2006–2009. As previously discussed, follow-up arrests occur when the police arrest the suspects of ongoing investigations. Therefore the number of pending investigations must be added in the interrupted time series' equation in order to control for the number of pending investigations per year.

Human resources. As discussed above, the second comparison was the comparison of human resources cost between ALPR technology and traditional policing. In other words, traditional policing and ALPR arrests are compared based on the number of police officers assigned to the shifts. Because there are eight mobile ALPR units in the city of Cincinnati, 75 to 100 police officers were assigned to these vehicles and units. In contrast, traditional police arrests can be standardised based on the number of police officers assigned to line duties. After standardisation, this study will identify any significant difference between ALPR and traditional policing units on the number of follow-up arrests made per officer as a measure of efficiency.

Given this context, the 'number of police officers assigned to ALPR units' and 'number of police officers assigned to traditional policing' will be employed as two independent variables. In this way, ALPR technology and traditional policing can be compared in terms of their human resources cost-efficiency for follow-up arrests.

Cost effectiveness. For the cost-effectiveness of an ALPR unit, a specific formula is used to compare the approximate $20,000 cost of a single ALPR unit to the overall savings (in human resources) per arrest. This formula is based on the difference in arrests between the ALPR units and traditional policing units. For example, if one mobile ALPR unit arrests 10 times more criminals than a traditional policing unit then the cost effectiveness of ALPR vehicle would be:

$$\begin{pmatrix}\text{Cost per ALPR patrol vehicle}\\ +\text{ sum of n number of ALPR}\\ \text{police officers' wages}\end{pmatrix} - \begin{pmatrix}\text{sum of i number}\\ \text{of police officers' wages}\\ \text{from trad. policing}\end{pmatrix} \times 10$$

That is, assuming that an ALPR police vehicle operated by three police officers for different shifts arrested 10 times[4] more criminals than n number of police officers from traditional policing, the cost-effectiveness of ALPR would be the sum of the cost of the ALPR vehicle and the wages of three police officers minus 10 times of n number of police officers' wages from traditional policing. The result will then be compared with the initial costs of the systems, with an overall projection established of how long it will take for the ALPR units to become a cost saving to the CPD.

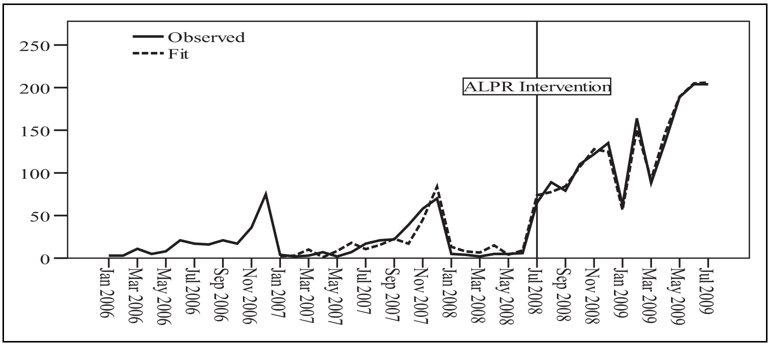

Figure 1. Identifying appropriate model for the data.

Results

The first interest of the study was to evaluate whether ALPR mobile units increased the number of follow-up arrests in the City of Cincinnati after the implementation of ALPR mobile systems. As noted previously, the appropriate analysis for this inquiry is interrupted time series analysis, which is also known as auto regressive integrated moving average (ARIMA) (McDowall *et al.*, 1980). When using time series data,[5] the potential problem is that adjacent time points or error terms can be correlated with each other, which in turn lead to biased standard errors and biased test results (i.e., t statistics). For this reason, correlated error terms, also known as the 'noise component', should be cleaned or whitened from the data in order to leave stationary/homoscedastic error terms for impact analysis (McDowall *et al.*, 1980).

Given this context, the first procedure in ARIMA is to find an appropriate model that ensures independent error terms with a mean of zero and a constant variance. This process is called the 'pre-whitening' procedure in ARIMA language (Granger and Newbold, 1986). An appropriate ARIMA model can be a combination of non-seasonal and seasonal models, which is modelled in ARIMA(p, d, q) (P, D, Q); where p is the number of autoregressive terms/orders, d is the number of non-seasonal differences and q is the number of moving average orders in the model. Capital P, D and Q stands for seasonality with the same explanations for p, d and q (Pridemore and Chamlin, 2006).

Figure 1 presents a time series graphic for the first dependent variable. The continuous line represents the observed number of follow-up arrests. The dotted line reflects whether the selected ARIMA models fit the observed data. As the figure suggests, the ARIMA (1,0,0)(1,1,0) model is a good fit to observed data. The non-seasonal part of the ARIMA model (1,0,0) indicates only autoregressive orders. An indication of autoregressive orders is that the previous time point predicts the current values. Yet the differencing process cleans pulses and ensures that the data are stationary. The moving average orders determine whether deviations from the series mean for preceding values are used to predict current values. However, Figure 1 visually suggests no indication for pulse function and moving average orders. Figure 1 also clearly shows seasonal correlated error problems for two reasons. First, the prior season's arrest patterns predict the current

Table 1. Model fit statistics.

Stationary R-squared	.958
Ljung-Box Q	.629

Table 2. ALPR technology and follow-up arrests.

	t-value	s.e.	p-value
ALPR technology	9.11	6.59	.00
Number of crimes	.110	.019	.91

season's arrest patterns (seasonal autocorrelation). In other words, as the figure suggests, toward the end of each year, follow-up arrest increases. Second, seasonal differencing occurs because the figure shows obvious seasonal pulse function. After these identifications, the ARIMA (1,0,0)(1,1,0) model appears to be the most appropriate model for the data.

In addition to this visual identification, a number of different goodness-of-fit tests should be used to figure out whether the selected model is the appropriate one. For this purpose, the most-used goodness-of fit-tests for time series data are stationary R-squared value and Ljung-Box Q statistic (Box *et al*., 1994). The stationary R-squared value represents how the model explained the total variation in the series. As in Ordinary Least Squares (OLS) regression, values that are close to 1 indicate better fits (1 is the maximum). In Table 1, the stationary R-squared value is 0.958, which suggests a better fit for the model of ARIMA (1,0,0)(1,1,0). Alternatively, the Ljung-Box Q statistic should be a non-significant value (less than 0.05). Finding non-significant values suggest that there is no systematic variation/structure left in the series. As presented in Table 1, the Ljung-Box Q statistic is much larger than 0.05, and suggests that the ARIMA model is correctly specified.

After the model fit process, the data are ready for ARIMA model because it ensures that the error terms are independent with a mean of zero and have a constant variance. Table 2 presents the test results for the analysis of whether ALPR technology increased the number of follow-up arrests in the City of Cincinnati after its implementation. The results in Table 2 indicate that ALPR technology substantially increased the number of follow-up arrests after its implementation (as of 15 July 2008). In order to account for the adverse effect of the number of crimes,[6] the number of crimes occurring each year are controlled in the model. The number of crimes, however, was not significantly associated with follow-up arrests and therefore did not mediate or negate the impact of ALPR technology.

Given this context, the findings suggest that ALPR technology increased follow-up arrests in the City of Cincinnati. In this analysis, however, the time series analysis provided a macro examination for the impact of ALPR technology. For this reason, further analyses (reported below) are needed to better evaluate the impact of ALPR technology on policing.

Table 3. Comparison of number of follow-up arrests by human resources cost.

	Traditional policing (1 Jan 2006 – 31 Dec 2008)			ALPR technology (16 July 2008 – 15 July 2009)		
	Average # of arrests	Average # of assigned officers	Average # of arrests per officer	# of arrests	# of assigned officers	Average # of arrests per officer
January	4	24	0.16	49	12	4.08
February	3	24	0.13	76	36	2.11
March	5	28	0.19	59	27	2.19
April	6	34	0.17	74	27	2.74
May	5	50	0.10	80	42	1.90
June	11	54	0.21	47	27	1.74
July	17	80	0.21	13	27	0.48
August	17	97	0.17	88	31	2.84
September	21	115	0.18	29	28	1.04
October	31	180	0.17	63	39	1.62
November	45	255	0.18	109	32	3.41
December	78	390	0.20	157	27	5.81
Total and Averages	242	111 (Avg)	0.17 (Avg)	844	30 (Avg)	2.5(Avg)

Human resources cost comparison results

The second interest of the study is whether the standardised number of police officers[7] working for ALPR units makes more follow-up arrests compared with the assigned police officers working in traditional policing. Table 3 shows a raw comparison between ALPR technology and traditional policing in terms of the number of arrests and number of assigned police officers. The monthly average number of assigned police officers for traditional policing was obtained from 'arrest by closure data'. All follow-up arrests were categorised yearly and monthly. The number of different assigned police officer names was counted in order to determine the number of officers assigned for unclosed/ pending investigations per month for each year between 2006 and 2008. Monthly numbers for assigned officers were then divided by three in order to acquire the three years' monthly average number of assigned police officers. As noted above, this procedure eliminates random fluctuations in the number of assigned police officers for a month. Similarly, the number of assigned ALPR officers was obtained by counting each different police officer name for the specific months during the 16 July 2008 – 15 July 2009 time period.

As presented in Table 3, based on monthly averages, 30 police officers were assigned to ALPR mobile units and conducted 844 total follow-up arrests during a one-year period. In contrast, an average of 111 police officers per month were assigned to follow-up arrests in the traditional policing system. These 111 police officers conducted a total of 242 follow-up arrests per year for the three years on average. In addition, Table 3 indicates the number of arrests and the number of assigned police officers per month.[8] In this context, while one officer assigned to an ALPR unit conducted 2.5 follow-up arrests per year, one officer assigned to a traditional policing unit conducted only 0.17 follow-up arrests per year.

Table 4 gives more detailed human resources cost comparison by crime type. This analysis includes follow-up arrests according to crime types (violent and property crimes) and the number of assigned police officers. Violent crimes include more serious crimes (i.e. homicides, burglary, assault), while property crimes contain less serious crimes, such as domestic violence and burglary. As the table depicts, traditional policing follow-up arrests overwhelmingly include violent crimes compared with ALPR technology. In contrast, ALPR movable units generally result in follow-up arrests for property crimes.

Table 4 also indicates the number of arrests per officer for both ALPR technology and traditional policing. For violent crimes, the difference between traditional policing and ALPR technology is low. The monthly average for violent arrests for a traditional policing unit is 0.17 per officer, compared with 0.21 for ALPR units. For property crimes, however, the difference is more tangible. As Table 4 reports, on average one police officer using traditional policing make no property crime arrests per month, while one police officer using ALPR technology makes an average of 2.30 property crime arrests per month.

Table 5 presents different aspects of human resources cost comparison by providing bivariate test results (t-tests). The first bivariate test compares number of monthly ALPR follow-up arrests with the number of monthly traditional policing follow-up arrests. As the results suggest, ALPR units conducted an average of 70.33 follow-up arrests per month. By comparison, traditional policing units only produced an average of 20.19 follow-up arrests per month. The result of independent sample t-test suggests that the difference between the ALPR units and traditional policing units is statistically significant.

The second bivariate test compares the number of monthly assigned police officers for the ALPR units with the number of monthly assigned police officers for the traditional policing units.[9] As Table 5 suggests, on average 29.58 police officers were assigned to ALPR units per month, compared with an average of 111.32 police officers assigned to traditional policing per month. In other words, there were 3.8 times fewer police officers assigned to ALPR units per month compared with traditional policing. This difference is significantly associated with any known critical regions in statistics ($t = -4.35$). The last two bivariate tests give more details in terms of follow-up arrest type. As noted earlier, violent crime arrests include serious crimes, and property crime arrests include less serious crime. In this context, the results in Table 5 demonstrate that while ALPR police officers made fewer violent crime follow-up arrests, they conducted more property crime follow-up arrests compared with traditional policing (5.42 compared with 20.08; and 65.25 compared with 0.11, respectively).

Even though bivariate test results suggest that police officers working in traditional policing units made more violent crime follow-up arrests compared with ALPR-assigned police officers, multivariate results will determine if this bivariate relationship remains statistically significant while controlling for other relevant factors. Recall that the number of number of police officers assigned to traditional policing was 3.8 times higher than ALPR police officers. When the number of assigned police officers is controlled in the

Table 4. Comparison of number of follow-up arrests by human resources and crime arrest type.

	Traditional policing (1 Jan 2006 – 31 Dec 2008)					ALPR technology (16 July 2008 – 15 July 2009)				
	Avg. # of violent crime arrests	Avg. # of violent arrests per officer	Avg. # of prop. crime arrests	Avg. # of prop. arrests per officer	Average # of assigned police officers	# of violent crime arrests	Avg. # of violent arrests per officer	# of prop. crime arrests	Avg. # of prop. arrests per officer	# of assigned police officers
July	4.00	0.16	0.00	0.00	24	7	0.58	44	3.67	12
August	3.00	0.13	0.00	0.00	24	4	0.11	72	2.00	36
September	5.33	0.19	0.00	0.00	28	3	0.11	56	2.07	27
October	5.67	0.17	0.00	0.00	34	4	0.15	70	2.59	27
November	5.00	0.10	0.00	0.00	50	1	0.02	79	1.88	42
December	11.33	0.21	0.00	0.00	54	2	0.07	45	1.67	27
January	15.67	0.20	1.00	0.01	80	0	0.00	13	0.48	27
February	16.67	0.17	0.00	0.00	97	5	0.16	83	2.68	31
March	21.00	0.18	0.00	0.00	115	1	0.04	28	1.00	28
April	30.33	0.17	0.33	0.00	180	6	0.15	57	1.46	39
May	45.33	0.18	0.00	0.00	255	7	0.22	102	3.19	32
June	77.67	0.20	0.00	0.00	390	25	0.93	134	4.96	27
Averages	20.08	0.17	0.11	0	111	5.42	0.21	65.25	2.30	30

Table 5. Human resources cost comparison.

	ALPR technology		Traditional policing		
	mean	s.d.	mean	s.d.	t-value
Total follow-up arrests	70.33	37.70	20.19	22.09	4.36*
Assigned police officers	29.58	7.61	110.94	111.32	−4.35*
Violent crime arrests	5.42	6.60	20.08	22.08	−3.54*
Property crime arrests	65.25	32.73	0.11	0.52	6.89*

*$p < .05$.

multivariate equation, the number of violent crime follow-up arrests for traditional policing units is 5.28 rather than 20.08 (20.08 divided by 3.8). Making this adjustment demonstrates that police officers working in traditional policing units did not conduct more violent crime follow-up arrests compared with police officers assigned to ALPR units.

In summary, the various aspects of the human resources cost analyses confirm that ALPR mobile units make more follow-up arrests with fewer human resources. Even though bivariate tests of violent crime arrests demonstrate fewer violent crime arrests for ALPR units, further adjustments based on the number of assigned police officers for each unit (traditional vs ALPR) indicated that there is no statistically significant difference for violent crime follow-up arrests between ALPR units and traditional policing.

Cost comparison results

According to CPD officials, patrol cars are equipped with ALPR technology for an additional cost of $21,500 per unit. As noted earlier, the CPD has eight ALPR mobile units for the City of Cincinnati. Therefore, the CPD has spent $172,000 for its current ALPR mobile units.

Personnel costs also represent an enormous portion of police departments' budgets. For the CPD in 2009, the average hourly rate for police officers and specialists assigned to patrol duties is $31.57. This translates to an average monthly salary of $5,051 (an average of 8 hours per day and 20 days per month). Recall that the average monthly number of assigned police officers to ALPR vehicles is 30, compared with 111 for traditional policing. By using this existing information, ALPR follow-up arrests and non-ALPR follow-up arrests can be compared for their cost-effectiveness. This formula is designed for this purpose:[10]

$$[\text{Cost of ALPR patrol vehicles} + \text{Sum of ALPR police officers' salaries}]$$
$$- [\text{Sum of police officers' salaries working in traditional policing system}]$$
$$\times \text{ Rate of ALPR efficacy}$$

Cost of per ALPR patrol vehicles = $21,500 × 8 = $172,000
Sum of ALPR police officers' salaries = $5,051 × 30
Sum of police officers' salaries working in traditional policing system = $5,051 × 111

Rate of ALPR efficacy over traditional policing for follow-up arrests[11] = 3.48
Therefore:
$[(\$172{,}000 + \$151{,}530) - (\$560{,}661)] \times 3.48$
$= -\$237{,}131 \times 3.48$
$= -\$825{,}216$

Based on these monthly averages (i.e. the average number of assigned police officers per month, and the average number of follow-up arrests), the above results can be interpreted as the monthly cost difference between ALPR and non-ALPR units for follow-up arrests. It might be expected that ALPR mobile units will cost police departments more money for a given month; however, when the efficacy rate of ALPR technology is taken into account, ALPR technology is cost-effective, as presented in the above comparison.

In addition to this cost-effectiveness, the cost difference between ALPR and traditional policing is noticeably large, which means that ALPR technology amortises itself in a very short time. In this case, for instance, officers using ALPR technology produce the same outcomes (in terms of follow-up arrests) for $ 825,216 less in a given month, compared with traditional policing. When the total cost of ALPR technology without the efficacy rate of ALPR technology and officers' salary expenses is taken into account ($21,500 per unit x 8 ALPR mobile units = $172,000) the ALPR mobile units amortised themselves in less than 21 days. If the efficacy rate of the ALPR technology is taken into account, the amortisation time would be less than seven days.

In contrast, it could be argued that there is not much difference between ALPR technology and traditional policing in terms of arresting violent crime suspects for ongoing investigations. In this scenario, the rate of ALPR technology to traditional policing would be one that reflects no efficacy rate. However, since traditional policing assigns more police officers for the same job (follow-up arrests) compared with ALPR units, the ALPR technology would amortise itself in slightly longer period. If we apply violent crime follow-up arrests to the above formula, the ALPR units would do the same job for $237,131 less each month. Therefore, considering only violent crime follow-up arrests, the ALPR technology amortises itself in less than one month.

Another previously unconsidered aspect of the cost-effectiveness of ALPR technology is that ALPR mobile units have high capability for the detection of stolen vehicles and identification of those delinquent on fines or otherwise failing to pay their legal obligations (i.e. traffic tickets). For instance, ALPR mobile units identified and recovered 147 stolen vehicles and released them to their owners within a one-year period. The CPD has also reported that ALPR mobile units detected over 2,600 vehicles with delinquent citations (Combs *et al.*, 2009). Considering these functions of ALPR technology along with the identification of criminals, ALPR technology amortises itself even more quickly.

Conclusion

There are few previous empirical studies regarding the impact of ALPR technology, and none that have addressed the specific hypotheses current posed; therefore, it is not possible to make comparisons between the current findings and previous studies. This study is one of the first systematically to evaluate the impact of ALPR technology on policing.

To assess the impact of ALPR technology on policing, various analytical techniques were used, including time series analysis, bivariate tests and cost-effectiveness analyses. The interrupted time series model examining the impact of ALPR systems indicated that ALPR technology significantly increased follow-up arrests in the CPD compared with more traditional policing approaches. The impact of ALPR technology was also assessed by conducting human resources cost-effectiveness analyses. Comparative human resources cost analyses revealed that ALPR technology carried out more follow-up arrests using fewer police officers compared with traditional policing.

In police departments, one of the concerns about adopting new technologies into daily police activities is financial cost. Like other organisations, police departments have scarce resources to maintain public safety; therefore, to maximise effectiveness and efficiency in crime prevention efforts they must rely on new technologies. ALPR technology has significant front-end costs and represents a substantial financial investment of departmental resources. The cost analysis of ALPR technology for the CPD, however, revealed that ALPR technology is cost-effective and amortises itself within less than one week. More specifically, ALPR mobile units effectively do the same job (produce follow-up arrests) with fewer officers compared with traditional policing. In addition to the follow-up arrest measure of effectiveness, ALPR mobile units have high detection capability for stolen vehicles and identification of delinquents who did not pay their legal financial obligations (i.e. traffic tickets, insurance). Adding these additional superiorities of ALPR technology increases its cost-effectiveness over traditional policing applications. From this perspective, ALPR technologies can be seen as a smart investment for police departments to allocate scarce resources optimally while effectively and efficiently enforcing the law and engaging in crime prevention.

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Notes

1. In ALPR policing terminology, a 'hit vehicle' refers to a vehicle with a licence plate number that is scanned by an ALPR unit and matches a law enforcement database.
2. Although, as noted, the CPD began using ALPR in April 2008, in the initial months of its implementation there were some errors associated with data collection. These were resolved beginning in July 2008.
3. Follow-up arrests, available in the 'closure by arrest' database described above, are used for this comparison instead of regular arrest data because ALPR technology only alerts to licence plate numbers that are included as suspicious or wanted in conjunction with still pending, rather than closed, investigations.

4. Multiplication process is only valid when the total cost of ALPR technology is lower than the total cost of traditional policing. If not, efficacy rate (in this case 10) should be used as a divider.
5. Time series data are a set of ordered observations that interest variable(s) are watched over time.
6. As the number of crimes increases, follow-up arrests also increase. For this reason, we introduced number of crimes as a control variable to the equation.
7. The number of assigned police officers is divided by the number of follow-up arrests.
8. For traditional policing, the average number of assigned police officers was measured as a three-year average of assigned police officers to follow-up arrests in order to control random fluctuations between years.
9. Police officers in traditional policing are assigned to 'investigation pending' incidents in order to finalise or close the ongoing investigation. The number of ongoing investigations directly impacts the number of assigned police officers to finalise the 'investigation pending' incidents. The number of assigned ALPR police officers reflects the number of police officers that worked in ALPR units for a given/specific month.
10. Please note that the 'Rate of ALPR efficacy' can be either multiplied or divided to the result of first section of the formula. For instance, if the sum of police officers' salaries working in traditional policing system is less than the sum of the cost of ALPR patrol vehicles and ALPR police officers' salaries, then the result should be divided to 'rate of ALPR efficacy' in order to adjust ALPR technology efficacy over traditional policing. In our scenario, this was not the case; therefore, we multiplied the result with 'rate of ALPR efficacy'.
11. This rate is based on the human resources comparison (monthly average of ALPR follow-up arrests/monthly average of traditional policing follow-up arrests = 70.33/20.19 = 3.48).

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