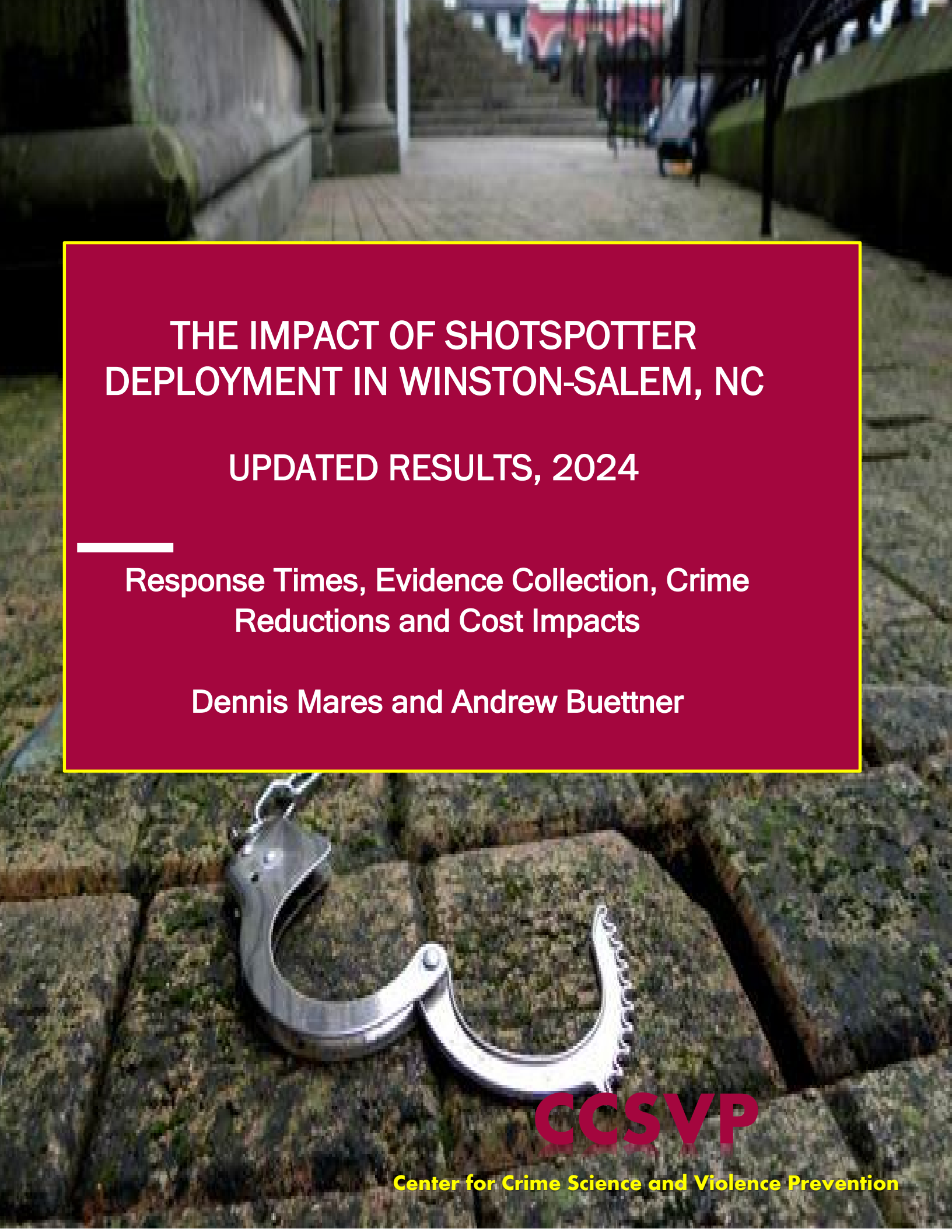

# THE IMPACT OF SHOTSPOTTER DEPLOYMENT IN WINSTON-SALEM, NC

## UPDATED RESULTS, 2024

Response Times, Evidence Collection, Crime Reductions and Cost Impacts

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## EXECUTIVE SUMMARY

ShotSpotter's gunshot detection system was deployed in Winston-Salem in August 2021. Since then, nearly 3,700 ShotSpotter alerts received a response by Winston-Salem Police.

Results indicate:

- Improved **response to gunfire**
  - The response to ShotSpotter alerts is significantly quicker than those called in by residents.
  - ShotSpotter calls for service received significantly more investigative time, which likely indicates improved evidence recovery.
  - Fewer than one in five (19.2%) of ShotSpotter alerts also received a call from residents.
- ShotSpotter produces the following **actionable results**:
  - 1,614 (43.3%) alerts produced distinct evidence of gunfire, 1,995 (53.5%) did not yield conclusive evidence of gunfire, and only 40 (1%) cases turned out to be confirmed false positives.
  - Shell casings were recovered in 1,372 incidents (36.8%)
  - Firearms were recovered in 139 (3.7%) of alerts.
  - 102 arrests are connected to 83 ShotSpotter alerts meaning 2.3% of alerts with complete data (3,657) yielded at least one arrest.
- Deployment of ShotSpotter is related to a **reduction in violent gun crimes:**
  - The ShotSpotter area saw a significant 24% reduction in assaults and homicides.
  - In real numbers, this translates to about 87 fewer assaults annually in the ShotSpotter area than would be expected.
- Cost-Benefits:
  - Our estimate suggests that ShotSpotter may save the Winston-Salem community between $8,425,000-$8,779,000 annually.
  - This indicates a $26 return for each dollar spent.

# INTRODUCTION

ShotSpotter is an Acoustic Gunshot Detection System (AGDS) which uses multiple sensors to detect the location of gunfire. After positive automated identification of the sound patterns of gunfire, acoustic events are reviewed by ShotSpotter personnel for accuracy. Once a final determination is made, an alert is forwarded to the police agency. Alerts are typically forwarded to dispatchers, also officers may receive notifications directly on their Mobile Data Terminals (MDTs) or mobile phones. Alerts include precise location data, the number of rounds fired and an accurate time stamp of the incident. Audio of the incidents can be accessed as well.

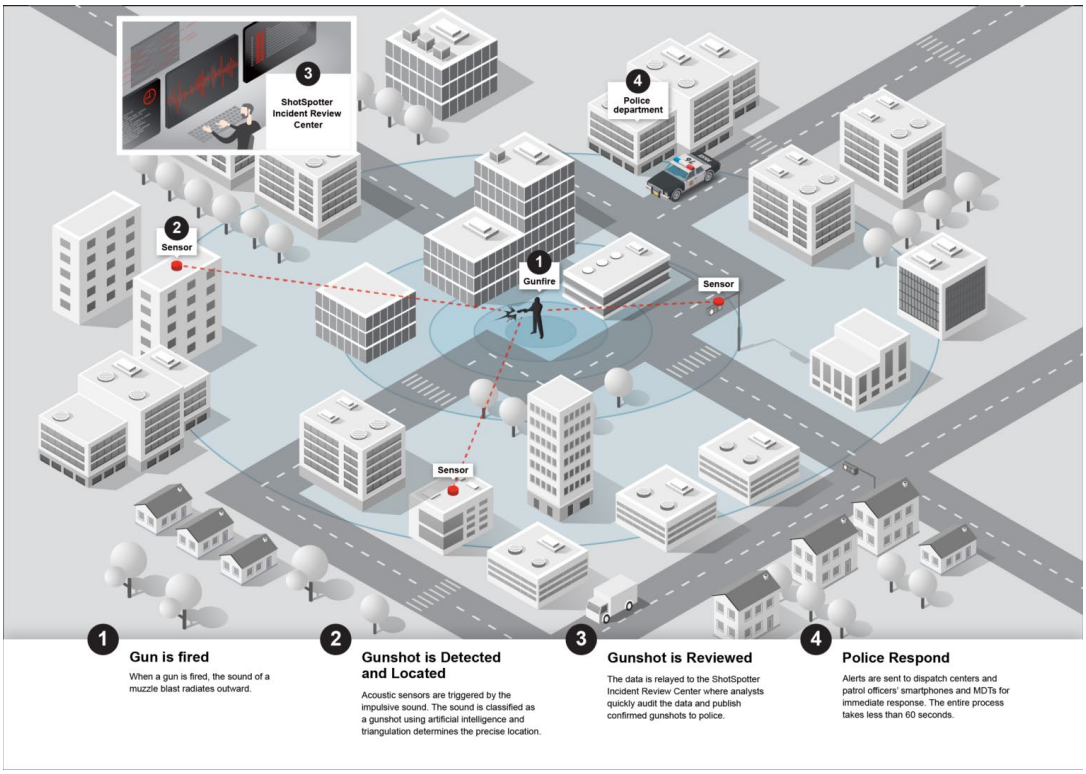


**Figure 1. Gunshot detection**
Source: https://www.shotspotter.com/law-enforcement/gunshot-detection-technology/

ShotSpotter systems have currently been deployed in over 150 cities in the US and the company is currently the leading vendor for gunshot detection systems. With respect to the accuracy of the system, the system appears to positively identify gunfire in over 80% of gunfire incidents in a field trial (Watkins et al., 2002), and the spatial accuracy is an improvement over calls for service from the public (Wheeler and Gerell and Yoo, 2020). Unlike other vendors,

ShotSpotter utilizes human reviewers after gunshot detection algorithms filter loud sounds down, to further limit false positives. Gunshot detection has typically been viewed positively by community residents (Haberman et al., 2020; Vovak et al., 2021). Moreover, 2/3 of the general public supports the use of the technology by police[1]. There are, however, some limitations to these systems. For example, they are unlikely to detect indoor gunfire but also have difficulty picking up gunshots fired from a vehicle. While false positives appear rare, they can be problematic in some circumstances, although the full extent of this issue remains unknown at this time.

Even though gunshot detection systems are probably deployed with the intent to reduce gun violence, academic research so far has found mixed results with respect to crime reductions (*cf.* Lawrence et al., 2019; Mares & Blackburn, 2021; Mares, 2023). Implementation differences, however, may explain the degree of success and agency experiences. There is little doubt, however, that gunshot detection improves the speed and precision of the police response (Piza et al., 2023), can improve evidence collection and may even hasten first aid to gunshot victims and expedite their transfer to trauma centers. In short, while violence reduction is often considered to be the primary aim of better gunfire information, ancillary benefits do potentially exist as well.

Below we will quantify some of the results ShotSpotter has brought to the City of Winston-Salem and how it has impacted police practices and outcomes. A cost-benefit discussion will also be provided.

[1] https://morningconsult.com/2021/09/13/data-privacy-security-gunshot-detection-technology-poll/

# SHOTSPOTTER IN WINSTON-SALEM, NC

In August 2021, ShotSpotter provided Winston-Salem with a 3 square mile area of coverage for its gunfire detection system. The area covered is located just North-East of Downtown, South-West of Smith Reynolds Airport and intersected by Highway 52.

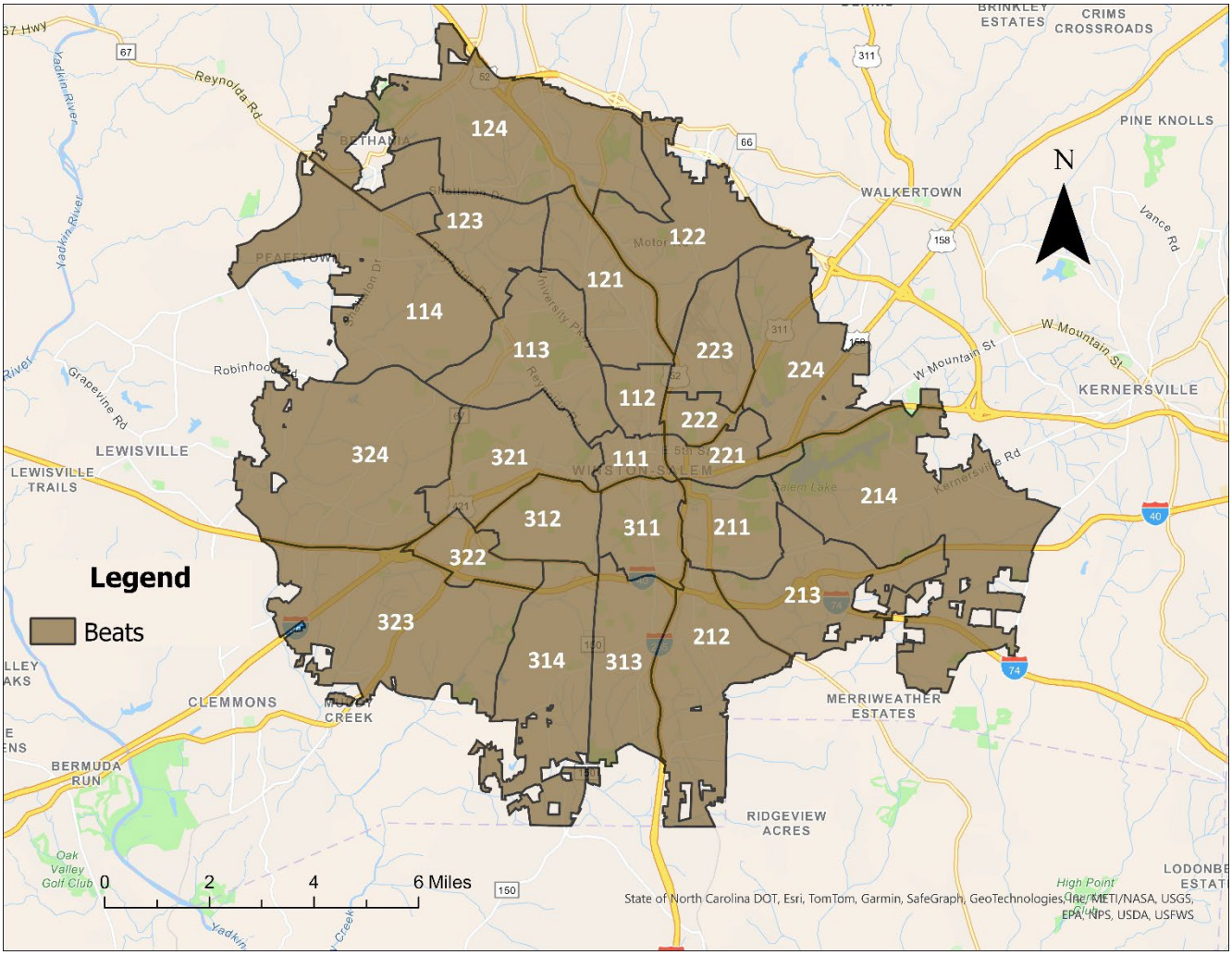


Figure 2. Winston-Salem Police Beats.

Between late August 2021 and January 2024, Winston-Salem Police Department (WSPD) responded to over 3,500 ShotSpotter alerts. This report details the results of the WSPD response to this technology and the alerts it provides. The report concludes with a cost-benefit assessment of the technology and implications for current policies and practices.

# RESPONDING TO GUNFIRE ALERTS

Winston-Salem PD officers responded to a large number of ShotSpotter alerts in the area that received coverage, but simply responding, of course, does not mean that this is an effective or efficient use of officer time (Blackburn & Mares, 2019). Below metrics will provide better context for the data.

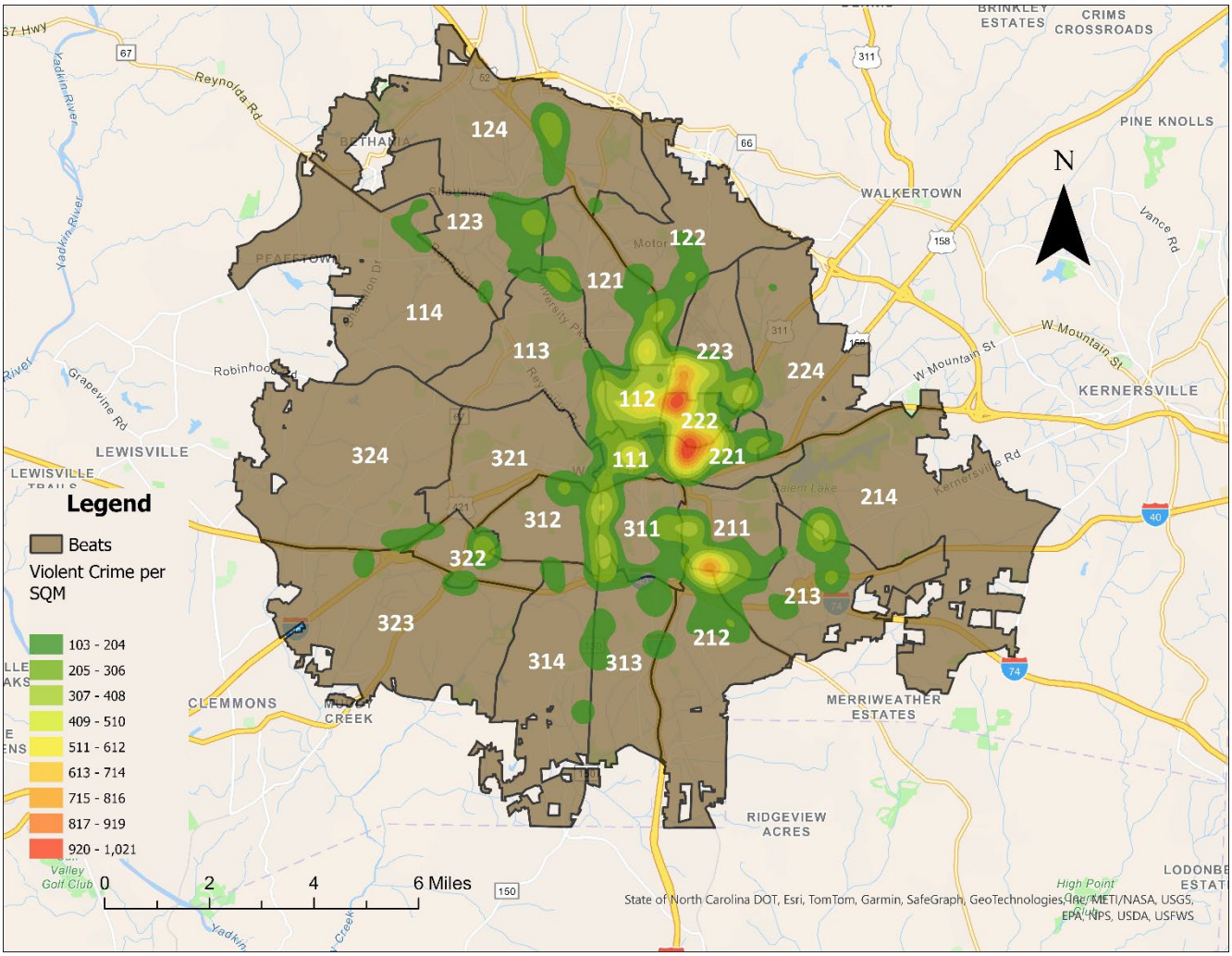


**Figure 3. Crime Incidents in ShotSpotter and Comparison Areas**

To make comparisons more meaningful a comparison area was created that shares some key characteristics with the area covered by ShotSpotter (see figure 3 above). Although no one area in Winston-Salem has quite the density of gun-related crimes as the ShotSpotter zone, an area with a relatively higher density of gun-related crimes, including several pockets of multi-family housing with even extremer densities was located. This comparison area is south of Downtown and east of Highway 52, running primarily along Interstate 40. The comparison area is a bit larger than the ShotSpotter area, 4.5 versus 3 square

miles, yet both have fairly equitable numbers of calls for service related to gunfire and a reasonably similar number of violent crimes (see table 1 below). That does not mean the two areas are entirely comparable but given that implementation of ShotSpotter occurred in the area of highest need, this is the closest comparison within Winston-Salem and provides likely a better comparison than using overall city data. Both the ShotSpotter and comparison areas share a large proportion of violent and gun related offenses in Winston-Salem. Combined they account for 30% of gunfire related calls for service (excluding ShotSpotter alerts) and 34% of violent crimes (excluding sexual assaults) within the city limits.

| INCIDENT TYPE | SHOTSPOTTER AREA | COMPARISON AREA | REST OF CITY |
|---|---|---|---|
| *CALLS FOR SERVICE** | | | |
| DSFA | 1,270 | 1,586 | 7,368 |
| DSFAD | 328 | 320 | 949 |
| SHOOTING | 217 | 141 | 500 |
| | | | |
| TOTAL CFS | 1,815 | 2,047 | 8,817 |
| | | | |
| *CRIMES* | | | |
| MURDER | 38 | 25 | 87 |
| ROBBERY | 262 | 138 | 941 |
| ASSAULT | 1433 | 867 | 4,275 |
| | | | |
| TOTAL CRIME | 1,733 | 1,030 | 5,303 |

**Table 1. Comparison of Calls for Service / Crimes July 2019-January 2024**
*Shooting includes call codes for: drive by shooting, person shot and GSW. DSFA, Discharging of a firearm, DSAFD, discharging of a firearm into a dwelling or vehicle.

Figures 4 and 5 below show some interesting pattern changes when ShotSpotter was activated in August 2021. In the ShotSpotter area, for example, we see a large drop in Discharging of a Firearm calls for service (DSFA). While those numbers were already trending down somewhat, they were reduced to a

smaller baseline post implementation, and remained low throughout our study period. By contrast (figure 6), the comparison area shows mostly steady patterns. A rapid decline in shots fired calls by the public was also seen in St. Louis' gunshot detection zone (Mares & Blackburn, 2021) and should not immediately be taken as evidence that gun crimes are down. Rather, it may suggest that calls by residents are replaced by ShotSpotter alerts, which now outweigh prior levels of calls by residents.

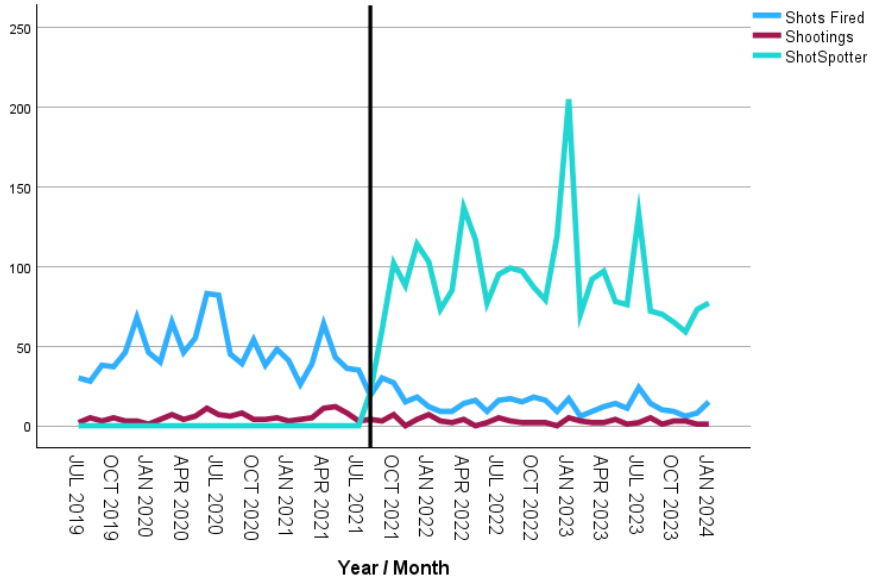


Figure 4. ShotSpotter Area. Monthly trends in gunfire related calls for service.

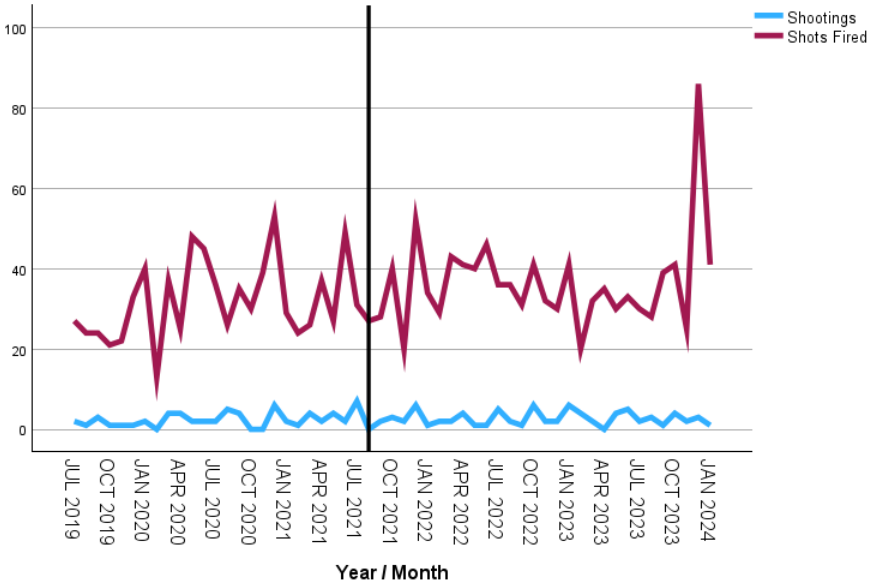


Figure 5. Comparison Area. Monthly trends in gunfire related calls for service.

To explore how ShotSpotter implementation may impact the response to gunfire we first examine response-time information, comparing gunfire related events reported by community members to ShotSpotter alerts. In table 2 below we can see, using median response times, that ShotSpotter alerts get dispatched almost two minutes faster than calls by residents, which is statistically significant. While travel time to the scene of a gunfire incident takes slightly longer for ShotSpotter alerts, this difference is under a minute and does not take into consideration that ShotSpotter alerts are more likely to occur at night when fewer officers tend to be available to respond (see also figures 9 and 10). ShotSpotter alerts, in other words produce an officer on scene more rapidly than calls from residents.

Interestingly also is that ShotSpotter investigations -on average- take much longer (7+ minutes) than calls from community members. This makes sense as knowing the precise location of gunfire increases the chances of finding and securing evidence.

| | SHOTS FIRED (DSFA) | SHOTSPOTTER ALERTS |
|---|---|---|
| DISPATCH TIME | 2.97 | 1.2*** |
| TRAVEL TIME | 4.68 | 5.45 n.s. |
| INVESTIGATIVE TIME | 17.18 | 24.62 *** |
| TOTAL TIME | 31.55 | 35.7 n.s. |
| CASES (N) | 221 | 2,291 |

**Table 2. Calls for service median times in minutes in ShotSpotter area.**
**Statistical significance is based on Mann Whitney U tests: * p<.05, ** p<.01, *** p<.001. Cases only included if a positive number was available for all call out times. In order to reduce temporal bias in the analysis, only cases post august 2021 were included for statistical tests. Excluded also were cases generated during July 4th and New Year..**

What the prior table does not tackle is whether the implementation of ShotSpotter has implications for how gunfire is responded to. To examine this, we compare response times before and after ShotSpotter implementation for several areas in Winston-Salem. Here we focus on gunfire-related calls (including both ShotSpotter and DSFA) for service. Table 3 below shows that the area covered by ShotSpotter has a significantly lower dispatch time, but significantly longer travel, investigative and consequently total time. Interestingly, dispatch times lengthened significantly in both the comparison and remainder of Winston-Salem, which makes the timesaving even more impressive. Where prior to ShotSpotter, dispatch times were within a minute of

each other across the three different areas, after implementation, the ShotSpotter area dispatched calls for service in nearly half the time, or 4 minutes faster.

| | BEFORE | AFTER |
|---|---|---|
| *SHOTSPOTTER AREA* | | |
| DISPATCH | 2.72 | 1.30 |
| TRAVEL | 4.17 | 5.37 |
| INVESTIGATIVE | 27.77 | 25.38 |
| TOTAL | 43.98 | 37.08 |
| | | |
| NUMBER CALLS | 1115 | 2684 |
| | | |
| *COMPARISON AREA* | | |
| DISPATCH | 3.27 | 3.78 |
| TRAVEL | 5.40 | 5.22 |
| INVESTIGATIVE | 21.82 | 22.2 |
| TOTAL | 39.33 | 47.6 |
| | | |
| NUMBER CALLS | 761 | 1000 |
| | | |
| *REST OF CITY* | | |
| DISPATCH | 3.1 | 4.12 |
| TRAVEL | 6.58 | 7.22 |
| INVESTIGATIVE | 20.05 | 20.90 |
| TOTAL | 36.40 | 43.23 |
| | | |
| NUMBER CALLS | 3683 | 4172 |

Table 3. Comparison of median calls for service times in minutes for gunfire related calls for service before/after ShotSpotter implementation.

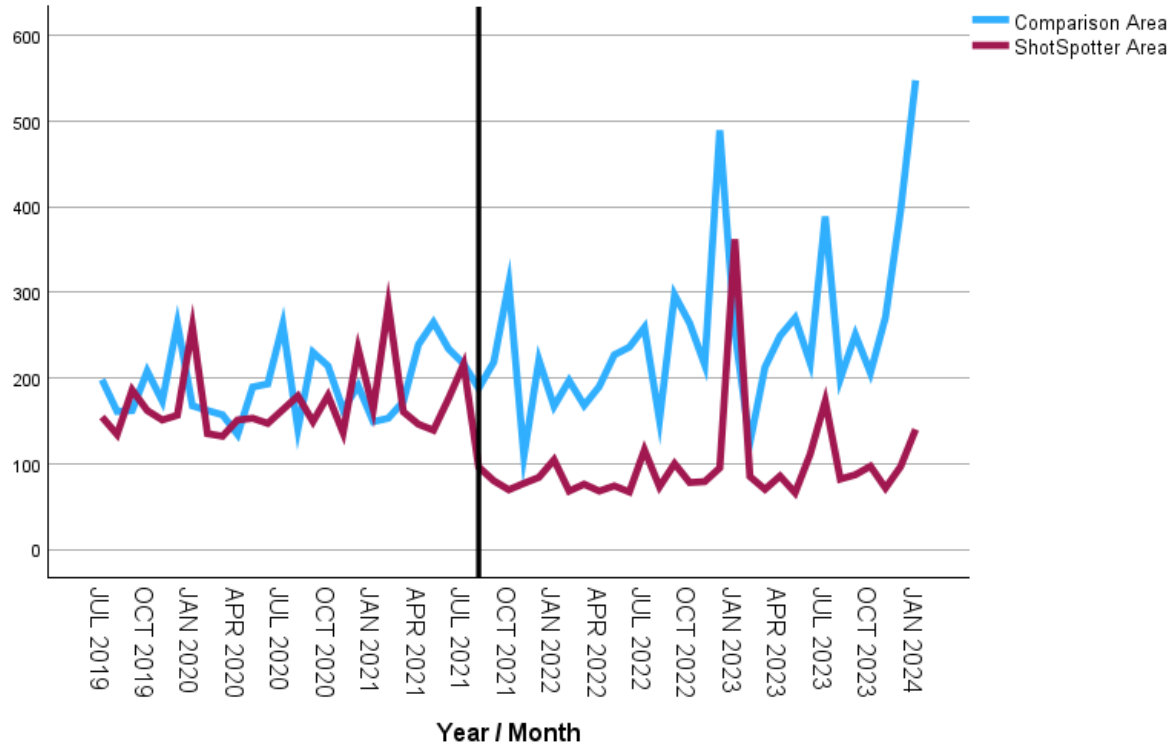


Figure 6. Median Dispatch times (seconds)

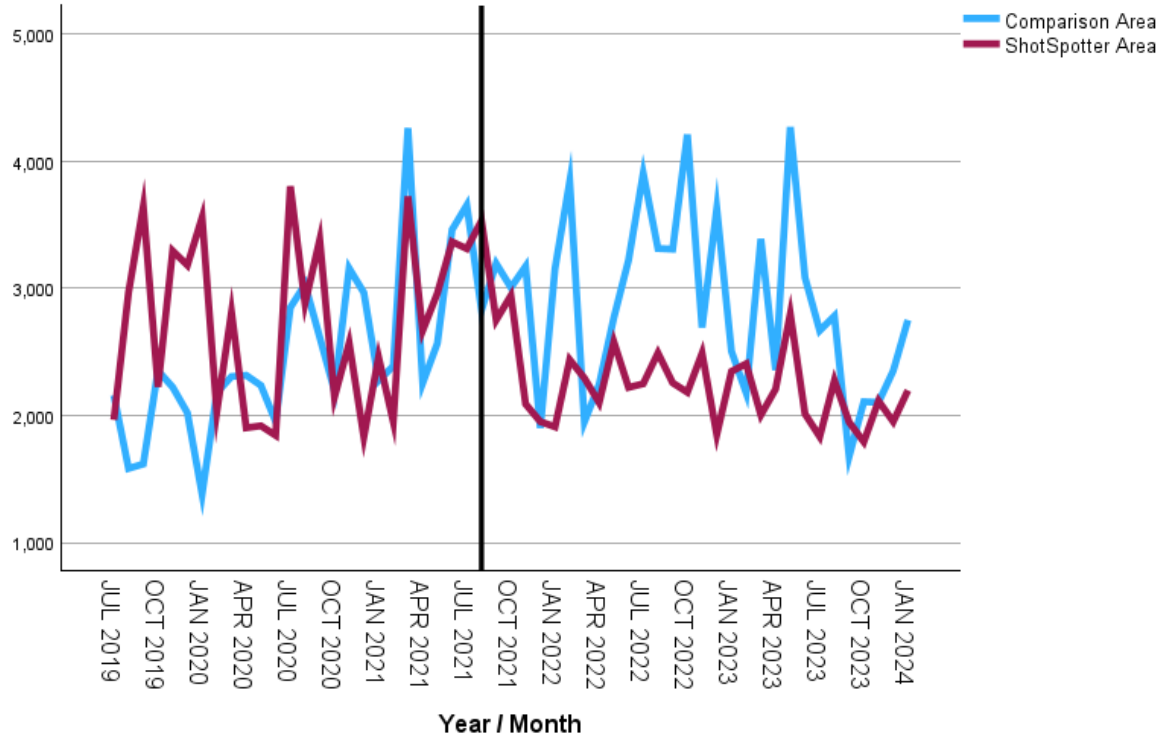


Figure 7. Total Median time spent on gunfire related CFS

Interestingly both the ShotSpotter area and the remainder of the city experienced an uptick in the time it took officers to get to the scene of an incident. While it is easy to read too much in these numbers, we suspect the increased travel times may simply be an outcome of declining officer numbers. As police agencies across the nation face growing attrition, this is not entirely surprising. Investigative times changed minimally for both the comparison area and the rest of Winston-Salem with the latter increasing proportionally the most. In the ShotSpotter area investigative time is reduced, which could be linked to reductions in violent crimes (see further below).

A difference-in-differences analysis provides more clarity how gunfire-related calls for service have changed while controlling for expected changes before and after implementation *and* concurrent changes in the comparison site. This type of analysis is commonly used to assess changes in 'natural experiments'. Table 4, details, for example, that the ShotSpotter area saw an overall and significant increase of gunfire calls for service of about 185%, meaning that this area now handles a much larger volume of such calls than expected. Naturally that is understandable given the fact that most gunfire is never called in. Excluding ShotSpotter alerts, gunfire-related calls for service are down 71% from anticipated levels, meaning that fewer residents call in gunfire. It may mean that gunfire is down, or it may mean that ShotSpotter alerts simply pre-empt calls from residents, or perhaps even a combination of the two; unfortunately, this type of data does not allow us to narrow down the exact reasons, however. Breaking gunfire calls down into shooting events (with a clearer intent to cause injury) and shots fired events (DSFA) we can see that the overall reduction is primarily, but not solely, driven by reductions in shots fired calls. Still, shootings are also 54% lower than anticipated, which indicates -in our view- that there are likely fewer potentially injurious shootings taking place as such serious incidents are likely to be called in by residents.

The pattern we see when comparing the ShotSpotter area against the comparison area is repeated when we perform the same analysis against data from the remainder of the city, indicating that the patterns in the ShotSpotter area stand out. This is further underlined when we perform the analysis comparing the comparison area against the remainder of the city, which yield small, statistically insignificant percentages.

| | SST VS COMPARISON | SST VS REST OF CITY | REST OF CITY VS COMPARISON |
|---|---|---|---|
| *CHANGE IN # CFS* | | | |
| ALL GUNFIRE CFS INCL. SHOTSPOTTER | +185%*** | +213% *** | -13% n.s. |
| GUNFIRE CFS MINUS SHOTSPOTTER | -71% *** | -67% *** | -14% n.s. |
| SHOOTINGS | -54% *** | -52% *** | -4% n.s. |
| DSFA / DSFAD ONLY | -73% *** | -69%*** | -14% n.s. |

**Table 4. Difference-in-Differences analysis comparing number of calls for service (cfs) before and after and between ShotSpotter area and Comparison/Rest of City. * p<.05, ** p<.01, *** p<.001, n.s.=Not Statistically Significant.**

In sum, results of response times indicate that implementation of ShotSpotter significantly reduced the time it takes police to respond to gunfire related calls for service and how long police investigate the crime scene. These results stand in contrast to the comparison area, which saw the exact opposite. It is fair to read such results as a positive development and improving the WSPDs ability to better serve the community. While the geographic accuracy and reporting speed of ShotSpotter is probably a large benefit to police, crucial information about shootings is often relayed by community members. Keeping residents connected to police and reporting gunfire is therefore extremely important.

# RESULTS OF SHOTSPOTTER RESPONSES

Because a new ShotSpotter alert can be generated after a few second pause in gunfire, it is important to clean ShotSpotter data prior to further use. We therefore remove alerts that occurred within 15 minutes and 1,000ft of one another to create a better representation of the number of unique gunfire incidents (Huebner et al. 2021). Out of the 3,690 alerts recorded we found that they represented 2,685 distinct incidents with a total number of 15,150 rounds detected (~5.6 average per alert). A small number of new alerts lack additional investigative updates and are also excluded from analysis. According to data tracked by WSPD, out of all shooting incidents with complete data (3,658) evidence for the occurrence of gunfire was found in 1,614 alerts (44.1%) firearms were recovered in 139 (3.7%) incidents, and casings were recovered in 1,372 incidents (37.5%) with a total of 3,476 casings recovered. We should point out as well that the number of casings recovered by responding to ShotSpotter alerts (3 sqm) almost matches the 3,597 casings found by responding to calls for service from the community in the entire city (134 sqm). Importantly, 102 arrests were effected from responses to 83 alerts (2.3%), indicating that arrests, while not common, are relatively more common than seen in other cities.

Shell case analysis further reveals that about 80% of identified shell casings are likely fired from handguns (i.e., 9mm, 357, 40, etc.) and about 8% are likely associated with long rifles (7.62, .223 etc.), which reflects national numbers on firearm use. It is also interesting that the average number of casings generated from resident calls is nearly 8, whereas that number for ShotSpotter alerts is 4.68, indicating that residents -unsurprisingly may be more likely to call in gunfire with a large volume but less likely to report incidents with fewer rounds.

Like other cities, few gunfire alerts generated by ShotSpotter also generated calls for service from community members (Huebner et al.,2021; Mares 2022). In only 716 (19.6%) cases was a ShotSpotter incident accompanied by a community call. Crime-wise, ShotSpotter alerts were connected to 109 aggravated assaults, 6 robberies and 24 homicides (3.9% of total alerts). Eighty-four (2.3%) arrests were effected as a result of the response to ShotSpotter alerts, which is higher than reported in other locations (Mares & Blackburn, 2021).

Delving a bit more into the data, we also look at which factors may explain why some ShotSpotter incidents may be more likely reported by residents. To

do so a statistical model was developed that measures the likelihood of a ShotSpotter alert also receiving a report by a community member (yes/no). We explored several possible explanative factors including: (1) the total number of rounds fired during the incident (2) the number of ShotSpotter alerts per incidents, (3) whether the alert led to the scene of a violent crime and (4) temporal variation (month, day of the week and hour of the day) as there is quite a bit of variability in when alerts occur (see figure 8 and 9 below, for example) and these do not fully match calls for service from residents.

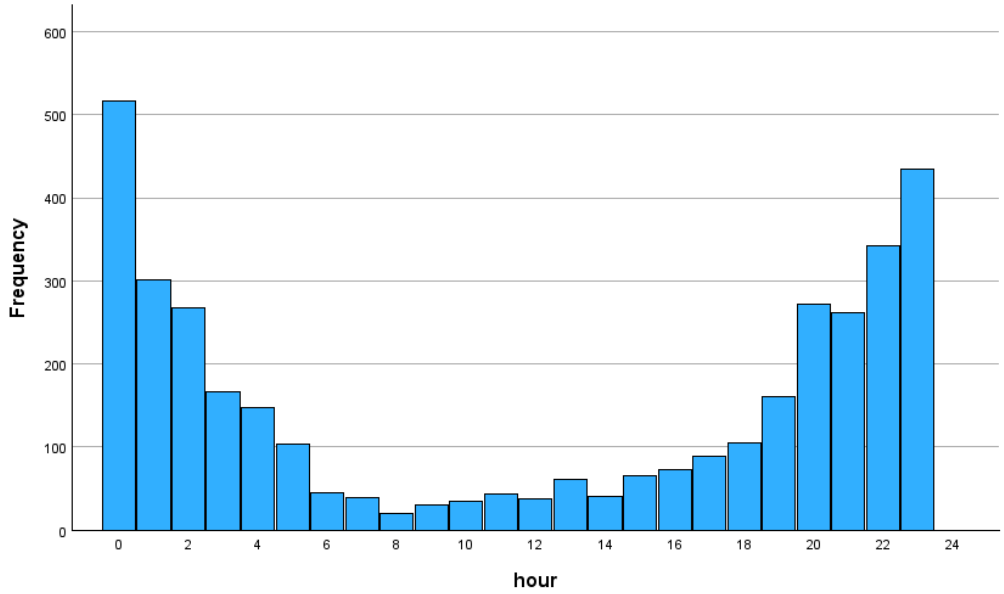


Figure 8. Time chart of ShotSpotter alerts, total alerts per hour.

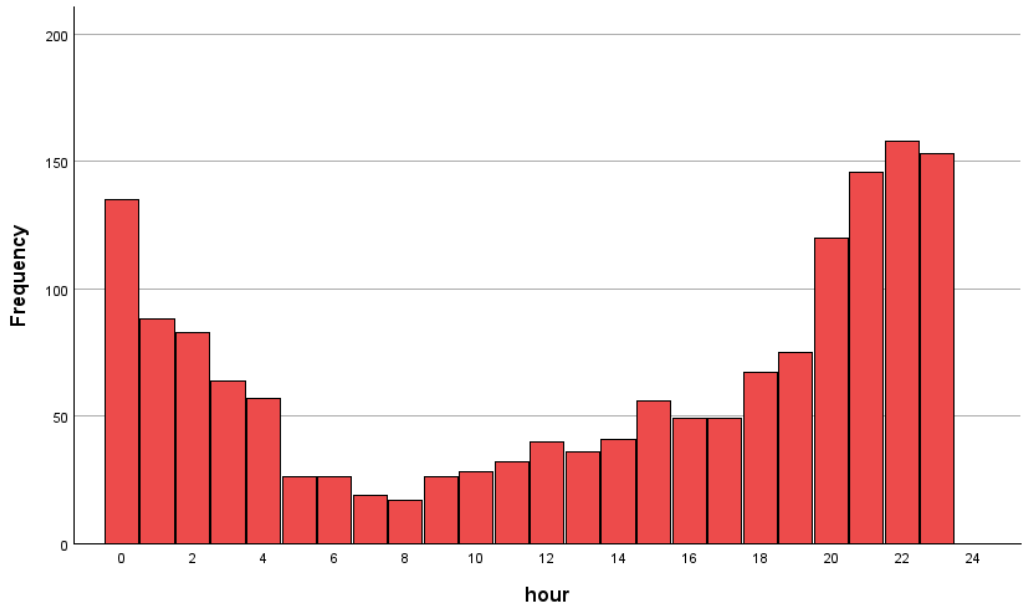


Figure 9. Time Chart DSFA/DSFAD calls for service, total calls per hour.

Findings of the statistical analysis indicate that the number of rounds fired during an incident *and* whether the incident was connected to a violent crime (assault, homicide or robbery) are key predictors of an alert also receiving a call from residents. Each additional round fired increases the likelihood of receiving a community call by around 10%. This is not surprising; more rounds mean more clarity on whether a loud sound is actually gunfire and also increase the chances that more people heard the gunshot. Violent crimes are also far more likely to receive calls from the community, probably because victims or bystanders notify 911. Our analysis suggests that violent crimes are 13 times more likely to be called in by community members than gunfire incidents without a victim.

While most alerts connected to a shooting victim also received a call from the public in addition to the ShotSpotter alert, about 18% of aggravated assaults, homicides and robberies did not, underlining the importance of gunshot detection in providing a rapid response for shooting victims. Incidentally this also may assist investigators identifying shooting locations as a fair number of assault victims are first contacted at hospitals and refuse to cooperate with police (Mares, 2022).

# CRIME REDUCTIONS

One of the key reasons police departments purchase gunshot detection is to tackle gun-related violent crime (Mares, 2023). With gunshot detection in Winston-Salem in place for a little over 2 years, a reasonable assessment can be made about its efficacy to reduce crime.

Beginning with serious violent crime committed with a firearm: homicides and aggravated assaults (see figure 10 and table 5). For the ShotSpotter area we observe lower levels of aggravated assaults and homicides after ShotSpotter implementation (-24%). By contrast the comparison area (and the remainder of Winston-Salem) display an initial growth in assaults levels that levels off, resulting in effectively no average change (+2%).

For DSFA (see figure 11), or illegal discharging of a firearm[2] the ShotSpotter area saw a substantial uptick in such incidents once ShotSpotter became active (represented by the black vertical line). Reported incidents increase from around 30 to about 80 per month (+146%). This is not surprising as ShotSpotter uncovers more such events. In the comparison area, the number of such incidents appears mostly stable, with no discernable trend (+0%). The remainder of the city also displays stable levels.

Robberies declined post implementation in all areas of Winston-Salem, but the relative decline was greatest in the ShotSpotter area (-19%). Charges for illegal carrying firearms (CCW) also were reduced by about 5% in the ShotSpotter area after the detection system became active, but increased by 17% in the comparison area.

[2] In WSPD RMS system this includes ShotSpotter alerts that are sustained as such, but also other calls for service in which a firearm was found to be discharged but in which no person was injured.

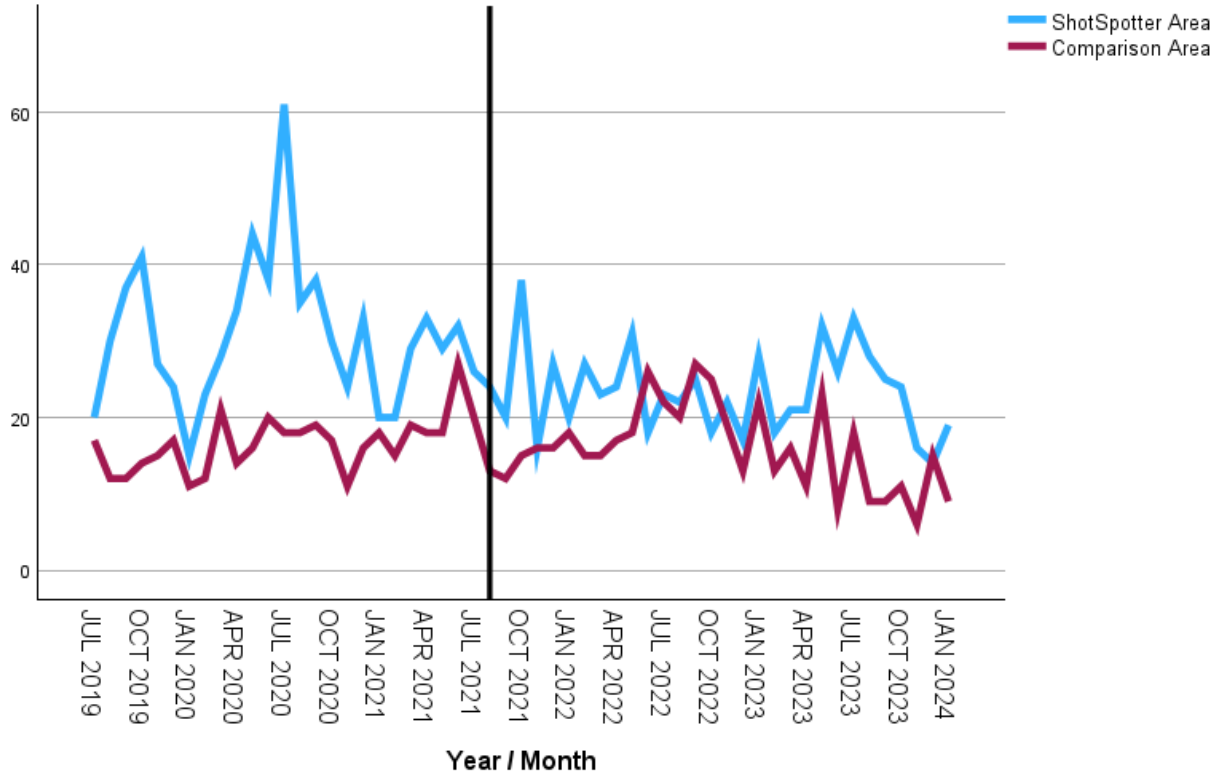


Figure 10. Aggravated Assaults and Homicides

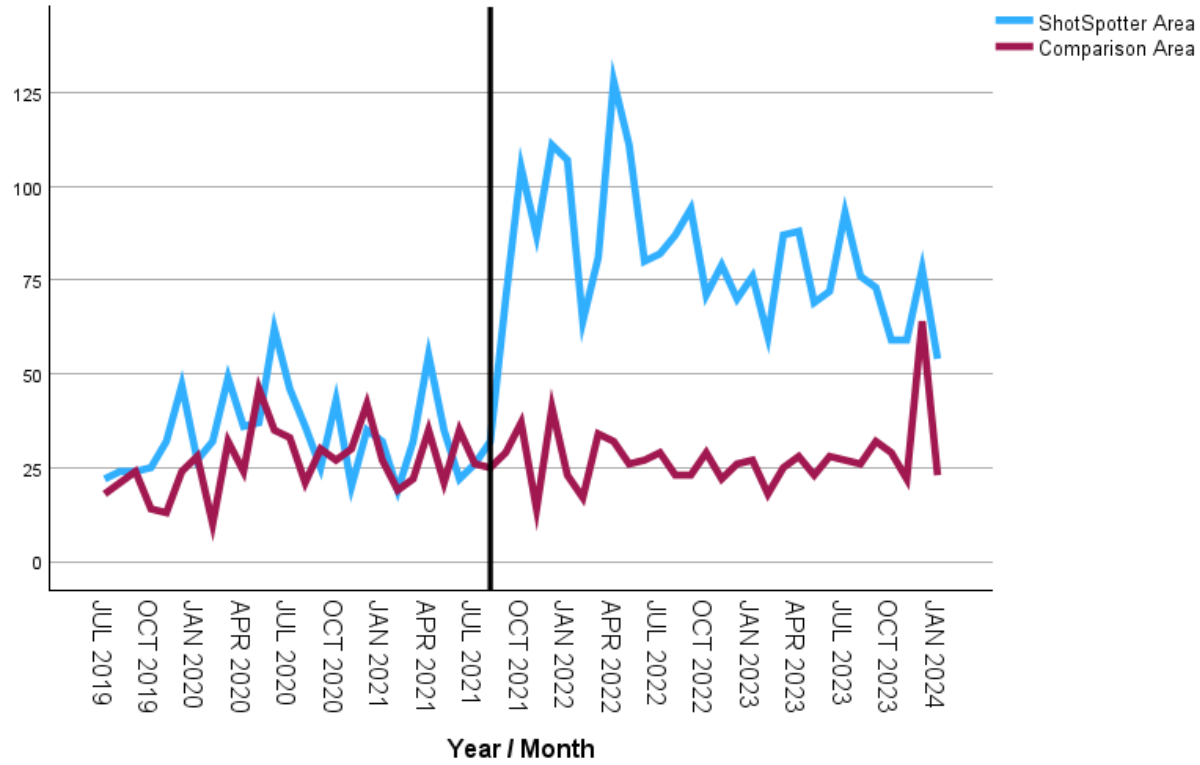


Figure 11. Discharging Firearm.

That said, trends lines can often be subjectively interpreted, so it is important to examine whether the trends described can be verified using more appropriate statistical analysis. To this, end we perform a Difference-in-Differences (DiD) analysis that compares average crime levels before and after ShotSpotter implementation while controlling for changes before and after implementation in the comparison area. DiD models are appropriate for exploring change effects in natural experiments and can make a reasonable claim for causality if the comparison group is equivalent to the experimental site.

| *Crime Type* | *SST area* | *Comparison area* | *Rest of City* |
|---|---|---|---|
| *Assault and Murder Before* | 30.84 | 16.60 | 78.44 |
| *Assault and Murder After* | 24.08 (-21%) | 17.08 (+2%) | 82.64 (+5%) |
| *Robbery Before* | 5.24 | 2.64 | 18.00 |
| *Robbery After* | 4.20 (-19%) | 2.36 (-10%) | 16.64 (-7%) |
| *CCW Before* | 5.96 | 3.76 | 16.04 |
| *CCW After* | 5.64 (-5%) | 4.40 (17%) | 16.80 (+4%) |
| *Discharge Before* | 33.72 | 26.28 | 121.88 |
| *Discharge After* | 83.20 (+146%) | 26.36 (+0%) | 124.24 (+1%) |

**Table 5. Comparison of before/after raw monthly crime levels.**

Results for various crime types indicate that the ShotSpotter area experienced substantial changes in crime incidents and those changes are consistent with those seen in the earlier trend graphs and table above We should caution to readers that both robberies and CCW violations are relatively rare for the ShotSpotter and comparison areas and that proportionally large swings in those number are somewhat expected, we therefore encourage interpretation primarily focus on the more numerous categories of aggravated assault/homicide and discharging of a firearm.

When comparing aggravated assaults and homicides in the ShotSpotter area before and after technology implementation and controlling for contemporaneous changes in the comparison area, the DiD model indicates that these crimes are significantly reduced by around 24%. Using the remainder of the city instead of the comparison area yields a similar reduction for the ShotSpotter area, about 25%

| CRIME TYPE | SST VS COMPARISON | SST VS REST OF CITY | REST OF CITY VS COMPARISON |
|---|---|---|---|
| *ASSAULT AND MURDER* | -24% ** | -25% ** | -2% (n.s.) |
| *ROBBERY* | -10% (n.s.) | -13% (n.s.) | -3% (n.s.) |
| *CCW* | -19% (n.s.) | -9% (n.s.) | +11% (n.s.) |
| *DISCHARGING* | 146%*** | 142%*** | -1% (n.s.) |

**Table 5. DiD analysis of monthly crime counts using negative binomial regression. ** p<.01, *** p<.001, n.s. not significant.**

The DiD analysis (table 5 above) largely confirms the results of the raw crime changes presented in table 4. Results for robberies (-10%) and unlicensed carrying (-19%) show downward trends in the ShotSpotter area, however, those results are not statistically significant compared to either the comparison area or the remainder of the city. This likely indicates the changes are a result of normal fluctuations in crime levels. For assaultive crimes (combining homicide and aggravated assaults), however, the 24% proportionate reduction is statistically significant, meaning these results are more consistent with actual changes rather than random chance.

For discharging of a firearm the situation is quite different, but again consistent with raw percent changes. Here the ShotSpotter area shows a very large and statistically significant increase, more than doubling prior levels (+146%). While these results might be viewed by some as alarming, they are in fact not and are in line with prior work (Mares & Blackburn, 2021) and an outcome of more events being reported and sustained through ShotSpotter (such as finding more casings). Because ShotSpotter alerts become added to community-driven calls for service the large increase is therefore most likely not an actual increase in people discharging firearms, but rather a reduction in underreporting that is common for such crimes. In this sense the increase really

represents an increase in potential opportunities for intelligence gathering (shell casing retrieval, increased witnesses, etc.).

What is not included above is a small but potentially important impact the improved detection and response speed may have. Several medical studies point out that a quicker response may -in some cases- prevent death or serious permanent disability to victims of gun violence (Goldenberg et al., 2019; Gontarz et al., 2021). Indeed, WSPD identified several cases in which victims received faster medical care that according to medical professionals likely saved their lives; in some of these cases only a ShotSpotter alert led police to detect a victim. While in such cases ShotSpotter did not prevent crime, it may well have reduced the seriousness of any injuries and deaths. The societal cost-savings of reducing the severity of injuries and possibly death are potentially substantial. Considering that the societal cost of a homicide can easily run in the millions of dollars, such cases could have substantial repercussions for the overall cost impacts of gunshot detection systems. The problem is that making this argument can only be robustly done with a large sample of data, likely involving multiple cities and a substantial period of observations. While we are sympathetic to this potential benefit, we had no feasible way to assess it with the current data and its limitations.

We would be amiss not to point out some limitations in the analysis. Our primary issue is that the comparison area is not fully comparable to the ShotSpotter area, as it had slightly lower gun violence levels than the coverage area. This may lead to under- or overstating found differences of the effect of coverage. What is more, 2020 and 2021 data were likely impacted by COVID-19 and the backlash against policing prompted by the nationwide protest after the George Floyd killing. Given the broader fluctuations in gun violence in the US during this era it may well have contributed to unusual swings in crime levels and growing heterogeneity across small places; in other words, the ShotSpotter area and our comparison site may have become more unequal in trends regardless of gunshot detection. In addition, areas with gunshot detection typically also receive additional attention by police, such as hot spots policing, or focused deterrence programs, for example. If such programs were run only in ShotSpotter areas, but not in other communities this could impact results. In short, some caution should be given to the conclusions, and they should be regarded as highly indicative, but not definitive.

# COST IMPACTS

Because aggravated assaults are the driving force of violent crime trends in both the ShotSpotter and Comparison area and because this category in particular shows significant reductions in crime after implementation of ShotSpotter, we can use this to calculate the impact of ShotSpotter on the cost of crime. To do so we can use two established methodologies to explore: (1) estimated additive cost and (2) Willingness-To-Pay estimates. Additive cost approaches are essentially a simple tallying of all the costs that are incurred by crime, such as medical cost, lost wages and criminal justice related costs. Willingness-To-Pay (WTP) approaches rely on economic research that suggests a simple additive cost approach may be less accurate as it does not reflect the subjective value that people assign to crime concerns. WTP estimates instead rely on asking a large number of people how much they are willing to pay for a specific percentage crime reduction.

For an estimated additive cost, data from RAND, estimates the average cost of an Aggravated Assault at $128,937.40[3]. Because the cost-of-living in Winston-Salem is below the national average, we adjust for this[4] and derive a localized cost of $104,826.11. Using the pre-ShotSpotter average monthly number of aggravated assaults in the ShotSpotter area between July 2019 and August 2021(30.24) and factoring in the crime reductions achieved in the Difference-in-Differences model (-24% or 7.26 fewer monthly incidents) this represents a reduction of about 87 aggravated assaults per year, or an annual cost-savings of about $9,129,000.

Using WTP estimates from Cohen et al. (2004) we find that serious assaults are estimated here to cost an inflation-adjusted average of $124,063 Adjusted for the cost-of-living in Winston-Salem this brings us to an estimated cost per aggravated assault of $100,863.54, or approximately $8,775,000.

Of course, ShotSpotter costs money and so does the response to the additional gunfire incidents as well as the increasing demand for evidentiary processing. The current ShotSpotter contract for Winston-Salem costs the city about $205,000 annually. In addition, the WSPD will respond to additional calls for service (ShotSpotter alerts). While this does not incur additional personnel

[3] https://www.rand.org/well-being/justice-policy/centers/quality-policing/cost-of-crime.html with inflation adjusted using https://data.bls.gov/cgi-bin/cpicalc.pl?cost1=87%2C238.00&year1=200701&year2=202301
[4] https://www.bestplaces.net/cost_of_living/city/north_carolina/winston-salem

costs -they are already on duty and responses are primarily in otherwise low volume hours (see figure 6), it will incur additional wear and tear on vehicles and increase gas usage. Using the federal mileage rate of 67 cents/mile (2024) we can estimate -very roughly- the cost of the immediate response. Assuming an average speed of 45 miles per hour, or .75 miles per minute the average travel distance to and from a ShotSpotter alert is 2x (.75 x 6.87) = 10.3 miles, or a cost of $6.90. multiplying this by the number of alerts per year (1,500) this would only add about $10,350 for a single vehicle response. However, it is more likely that two or more vehicles may respond and in some cases EMS vehicles may also be needed. To be conservative we believe it is reasonable to put annual vehicle related response cost at around $25,000.

It is also important to assess what the additional investigations would cost. Most aggravated assaults/homicides will eventually be discovered by police and require investigative resources. Arguably ShotSpotter may save some resources by pointing detectives to a more accurate location and time of an incident. This should reduce the time needed to search for evidence and review of video evidence. Further, given that our study shows the system reduces aggravated assaults/homicides by nearly a quarter, it is more likely that investigative cost would be smaller. What may push up investigative costs is the enhanced recovery of shell casings. It is not easily determined what the cost of evidence processing may be. ShotSpotter delivers a substantial increase in casing recoveries. From August 2021 through January 2024 records show ShotSpotter alerts led to recovery of 3,476 shell casings, compared to 3,597 casings recovered in the city from 911 calls. Estimating the cost of processing these rounds is not easy, as it involves handling by personnel to file and trace the casings as well as the cost of the machines that perform the tracing. What is more, not all casings recovered will need tracing, some are too deformed to reliably match, some may be part of a large number of similar rounds. Just the same if we want to be extremely conservative and price processing for each casing at $100, the total cost is still fairly non-consequential for the overall cost-benefit picture. Annualizing the casings recovered would mean about 1,200 casings per year at an annual cost of $120,000.

In sum, while the cost-savings, based on crime prevention can be estimated anywhere between $8,775,000 and $9,129,000, whereas the costs of increased surveillance and enforcement are somewhere near $350,000 per year. This produces a positive picture or $8,425,000-$8,779,000. It should be

pointed out, however, that while the savings are shared by all in Winston-Salem, the costs are entirely on the WSPD side.

# CONCLUSIONS AND RECOMMENDATIONS

Results of our analyses show largely positive results from WSPDs implementation of ShotSpotter's acoustic gunshot detection system. The data indicate a substantially faster response time in the ShotSpotter area and a reduction in serious violent crimes committed with a firearm (significant 24% reduction in aggravated assaults). Anecdotally the system also improves health outcomes for victims of gunfire, but this is more difficult to establish with current data. Finally, the system appears to improve investigative outcomes by returning substantially more shell casings and increasing arrests for gun-related offenses. These results are certainly encouraging and indicative of a sound implementation by WSPD.

As our results indicate, the benefits of ShotSpotter appear to outweigh the cost of the city's investment in the technology with a net annual gain to society of about $8,500,000 indicating a 26 dollar return for each dollar spent. That by all accounts appears to be a solid investment in limited resources. We believe it is therefore reasonable to support continued investment in the technology by WSPD.

It is somewhat puzzling that this is one of the few studies showing a strong benefit, as most studies present mixed findings with respect to gun crime reductions (see Mares, 2022). That said, results are in line with other agencies that have shown adherence to best practices, such as Cincinnati (Mares, 2023). It may therefore be reasonable to conclude that implementation practices (based on well-developed policies) may offer an important insight into the success of the technology to reduce gun violence.

In sum, ShotSpotter deployment in Winston-Salem shows strong potential and success based on the current data. We encourage WSPD to continue careful tracking of results. We also commend WSPD for how well it collected and compiled the data and the results connected to their response to ShotSpotter investigations. Close tracking of these results is important because crime reductions by themselves may not only be rooted in deterrence, but also in investigative work. We would encourage the department to track how ShotSpotter generated evidence (casings and alert data) assist in prosecution of gun offenders. This will likely become more important over time but may provide important insights beyond those examined here.

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CCSVP works with Criminal Justice agencies and community organizations to reduce violence and evaluate ongoing efforts to minimize gun violence. We advocate for collaborative, evidence-based and data-informed actions to serve public interests and those working in the broader criminal justice field.

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