University of Nebraska at Omaha

Department of Technical Writing

6001 Dodge Street

Omaha, NE 68182

ckozeny@unomaha.edu

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Thom Davis, CIST 3000 Instructor

University of Nebraska – Omaha

6001 Dodge Street

Omaha, NE 68182

Dear Professor Davis,

Herein you will find a report regarding the use and implementation of a Gunfire Detection System (GDS). The need for these systems lies in its ability to locate and report on illegal gunfire within a cities limit. Information regarding their implementation, cost, and public response can be found within.

The purpose of creating this report is to outline the positives and negatives of a Gunfire Detection System in an urban environment. This document pertains to a project completed as a part of my curriculum at the University of Nebraska at Omaha in Fall of 2018. The need for a reduction of illegal gunfire in cities couldn’t come at a more fitting time – local establishments and schools are being preyed upon, and citizens don’t feel safe wandering in their own neighborhoods. Gunfire Detection Systems work to combat this growing crime by pinpointing shooters at their location in less than a minute. Through manual and automatic situation assessment, company moderators and automated programs can confirm gunfire related incidents and dispatch alerts in real time. Implementation of a GDS (along with any other new system) can cause a large amount of growing pains for a city and law enforcement agency. These systems have their drawbacks and can prove to be an unhelpful resource in some areas – while others thrive on the technology and are able to leverage it to its full extent.

So, in a time where law-abiding Americans are in desperate need of a solution, what will lawmakers and local officials do to stand up to these criminals? The time to act on future innovations and possibilities is now. We can put an end to this issue before it grows out of control (and without confiscating your guns!).

Sincerely,

Christopher Kozeny

CIST Student

Gunfire Detection Systems in the Urban Environment: A Risk and Reward Assessment

for

Thom Davis

Technical Writing Instructor

University of Nebraska – Omaha

Omaha, Nebraska

By

Christopher Kozeny

CIST – 3000 Student

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***Executive Summary***

**Gunfire Related Crime and What We Can Do**

A solution to gunfire related crime in urban communities is an issue that no one can seem to agree upon. Every district and every company have their own way of “solving” the problem but no one solution is universal. Some areas require more attention and more policing, while others simply can’t get a grip on the crime affecting their cities. Gunfire Detection Systems can help minimize the issue with the help of a few key pieces. These systems can listen for gunshots and relay information to police regarding its location and the number of shots fired. According to a report by the American Public Health Association on gun violence, wrongful death tied to gunfire takes the lives of over 38,000 Americans every year. This is a gripping reality for communities that are seeing a multitude of unanswered deaths. With the help of systems like ShotSpotter and AmberBox, we can detect gunfire and act on it in a more efficient manner. Unreliable calls from civilians become unnecessary, and law enforcement agencies are able to respond to accurate, confirmed calls. The most pressing issue with most of the Gunfire Detection Systems in circulation today is the cost, both upfront and ongoing. A GDS working at full strength can quickly become costly. For a typical city, ShotSpotter can cost between $65,000 and $90,000 per square mile, per year. With the yearly price, subscribers to the service receive many benefits. For example, a user interface for the system to respond to with the location of shots, assistance from both a manual assessment response team and an autonomous one, sensor maintenance and upkeep from staff, and many more. Aside from the obvious tangible benefits from implementing a system like this, it can also work to deter crime in certain areas. In a case where offenders are aware of sensor locations, they will either conduct their business elsewhere or choose not to fire a weapon at all due to fear of retribution from law enforcement.

**The Science**

The science behind Gunfire Detection Systems has long been studied and examined. Sound Ranging technology has been around since World War I and is continually in use today. Furthermore, with the inevitable advancements of technology, this system has become even more precise. Aside from just “triangulating” the location of a shot, modern sensors can now detect the type of firearm used, the number of shots fired, and can even validate that the noise heard was confirmed gunfire.

**Gunfire Detection and the Future**

Gunfire Detection Systems have seen a lot of improvements since their original usage in military settings. They’ve adapted to listen more precisely for certain types of fire, detect and report the location, and offer details regarding the incident. This technology has made its way into city-based deployments and has even developed into GDS contracts with public schools across the U.S.

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(Source: AmberBox)

Despite some of the drawbacks that come with implementing a new project like ShotSpotter, cities can quickly see the benefits provided by such a high-tech system. Communities immediately feel safer and more secure, officers feel more connected with the community they patrol, and criminals are able to quickly and efficiently be apprehended.

**Typical Reporting**

With typical eye witness reporting, testimonies are unclear and hard to validate. Citizens call in and say they “think” they heard a shot, or that it “probably” came from over there. To law enforcement, this information is usually useless. In addition, civilian reporting of gun related crime is notoriously low. In fact, according to a popular report done by Jillian Carr, for Washington D.C., only 12.4% of gunfire related incidents (that were confirmed by ShotSpotter) were reported to the police.

**Recommendations and Conclusion**

When it comes to detecting gunfire, it’s always a double-edged sword. The additional hands-free reporting from an automated system is certainly a driving benefit. But the underlying cost and time associated with the process can sometimes be better utilized in other areas. Local governments and districts will have to decide for themselves. There are many different factors that go into deployment of a successful system, and every location differs in their needs.

***1.0. Introduction***

Gunfire Detection Systems (herein referred to as a “GDS”) are a resource being used by local law enforcement and government agencies to locate and arrest citizens discharging firearms illegally. In response to growing community concern and the burden of unregulated violence, control and containment of gun violence within our cities is an ever-growing problem. Gun violence is becoming an epidemic in the United States, and guns kill more than 38,000 people each year (“Gun Violence”, n.d.). Local law enforcement agencies and worried citizens crave a solution to these issues and are more willing than ever to find and act on such solutions. Gunfire Detection Systems have become one of the more prevalent and advanced solutions to curtailing the unlawful use of firearms.

The utilization of gunfire detection systems has been the latest trend in order to stop these criminals. One of the most prevalent outdoor systems deployed within city limits is called ShotSpotter. According to the ShotSpotter FAQ, “ShotSpotter is used in more than 90 cities across the United States and is highly regarded by law enforcement as a critical component of gun violence prevention and reduction strategies” (2018). Despite the documentation and self-praise by ShotSpotter, Inc., not all communities and law enforcement agencies have touted the success of their newly implemented GDS’s. The accuracy of a GDS, as well as the methods of reporting and detection have yet to be proven and many cities believe the funds and resources needed to keep these systems operational could be better used elsewhere.

There have been success stories and court cases ruling in favor of ShotSpotter and other GDS data. Conversely, there have been an equivalent amount of deployment failures and GDS shortcomings that weren’t foreseeable when city governments signed on the dotted line. This report provides a comprehensive look at gunfire detection systems and their effectiveness amongst the cities that use them. Within you will find extensive information regarding their origination, application, and reliability within an urban city environment.

***2.0. Understanding Gunfire Detection Systems***

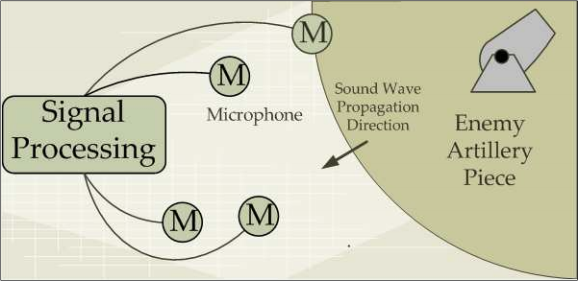
Gunfire detection systems come in a broad range of types. There are indoor and outdoor sensors, individually mounted sensors, vehicle mounted sensors for military use, and even counter sniper gunfire detection systems. These all differ based on the way that they listen for and detect gunfire. Every weapon has a distinct sound wave form and a unique rate of fire, so the individual specialization of these systems allows for and promotes a more precise and accurate detection.

**2.0.1. Origination**

Gunfire detection systems have long been in use by government agencies and military forces around the world. Its origination began with the first World War, when the brunt of the fighting and bloodshed was coordinated by artillery attacks. Faced with this, military officials needed to find a method useful for locating enemy artillery locations. Captain Harold Hemming, a Canadian artillery officer serving with the British 3rd Army, observed muzzle flashes and used this information to locate artillery positions on the battlefield. Hemming and a group of well-known British scientists furthered this understanding by developing a process known as “sound ranging” (“Flash Spotting”, n.d.). According to the Loyal Edmonton Regiment Military Museum:

The process involved a network of listening posts equipped with microphones and oscillographs that recorded the strength and direction of sound waves. The time intervals between listening posts were recorded and then triangulation was used to calculate the exact location of the gun. (“Flash Spotting”, n.d.)

This process of triangulating the source of sound waves was later used with radio waves. Advancements of sound ranging methods are accredited with paving the way for modern day radar and its further utilization in World War II (Cowen, 2017).



*Figure 1 – A depiction of how sound ranging and triangulation can be used to locate enemy artillery positions.*

**2.0.2. Later use of the System**

Gunfire detection systems saw many adaptations throughout the years. The use of a GDS throughout military settings and later into urban environments has become increasingly prominent. Acoustic sensors used in modern day gunfire detection systems, such as those utilized by ShotSpotter, are light years ahead of those used in World War I 100 years ago. These sensors can detect a range of different acoustic events - ranging from explosive bursts, rapid succession gunfire, and the ability to filter out background noise from noisy city environments. Their detection and response are much more efficient, and home-base type locations allow for the filtering out of ‘gunfire’ events that may not actually be gunfire at all.

**2.0.3. Popularity of Gunfire Detection Systems**

The usefulness of gunfire detection systems in a civilian setting has been brought to light following the increase of gun-related tragedies throughout the homeland. The use of smaller, indoor sensors has increased in popularity following school shootings like Sandy Hook and the school shooting in Parkland, Florida. Jennifer Russell, co-founder of EAGL Technology – a company developing and selling an indoor gunfire detection system – says EAGL has seen an increase in inquiries (about the system) since the Parkland shooting in February of 2018 (King, 2018). Although it isn’t ideal that these events spark the need for gunfire detection systems, it demonstrates that the public is responsive to societal change and willing to adopt – and fund – new technologies in an attempt to fight this type of rising crime.

Cities across the nation are adopting both indoor and outdoor systems in order to combat gun violence. Ranging from small cities like Glendale, Arizona, to roaring metropolitan areas as large as Chicago and New York City. ShotSpotter covers over 90 cities across the U.S., many of them a large difference in complexity of city landscapes and population sizes (ShotSpotter FAQ, 2018).

**2.1. How Detection Works in Real Time**

Proper detection of a bullet being fired is reliant on many different factors. Many of these being microphones, an array of sensors, and computer-generated algorithms. All of these in conjunction can provide a fairly clear picture as to the legitimacy and location of a gunfire incident. Each of these rely on a specific range of inputs, and only respond and react to an incident that meets a pre-determined criterion. Many of the consumer grade gunfire detection systems available today are self-learning in order to prevent future false alarms or have dedicated response centers that review the data before confirming that a gunfire incident is in fact genuine. The information contained within this section outlines the importance of all of these inputs together as a whole.

**2.1.1. Acoustic Sensors**

One of the three important sensing features of a gunfire detection system involves the use of acoustic sensors. These sensors don’t necessarily listen for sound in the typical way of a microphone, but instead “feel” for the shockwave of a bullet traveling through the air. A bullet leaving a firearm gives off a very distinct, signature sound wave. Most bullets travel faster than the speed of sound (why you see a gun fire a split second before hearing the blast) and the shock wave expands as a cone behind the bullet, with the wave front propagating outward at the speed of sound (Maher, 2006). Over time and distance, this shockwave deteriorates. Along with that, this type of shockwave isn’t always heard, for example, if you’re at more than a 90° angle from the line of fire. This can cause an issue for readings from these sensors, even more so with the addition of buildings and high winds within a city.

**2.1.2. Microphones**

In addition to acoustic sensors used to sense the shockwave of a bullet, one of the most important triggers for a gunfire detection system is by the use of multiple microphones. These microphones detect the ‘pop’ of a firearm being discharged. This is the sound that most people recognize (or think they recognize) when a bullet is being fired. To the human ear, this can easily be confused with the backfire of a car or motorcycle, fireworks, or construction being performed. The sound waves captured from the event can be immediately analyzed by A.I., or sent to an Incident Response Team to review the data and analyze and confirm the shot.

**2.1.3. Infrared**

Infrared sensing is also an important aspect to the gunfire detection system as a whole. Infrared sensors can be described as “instruments that can sense infrared energy—such as night-vision goggles or infrared cameras– (which) allow us to "see" the infrared waves emitting from warm objects such as humans and animals” (Science Mission Directorate, 2010). These sensors are typically used within a GDS to recognize the muzzle flash of a weapon. When a shot is fired, the hot, expanding gas that emits from the barrel gives off a very recognizable heat signature. This signal can be picked up by infrared sensors (given the flash was within view of the sensor) and can give additional support of confirmed gunfire to inputs received by the accompanying sensors and microphones.

**2.2. Location and Accuracy**

Where the sensors are located are of paramount importance to their reliability and accuracy. Gunfire detection systems use triangulation to pinpoint the location of a shot, so the sensors and microphones must be placed at regular intervals within an area. Depending on the landscape and obstacles, some areas may need a high-density number of sensors in order to be accurate.

**2.2.1. Frequency and Distance Between Sensors**

One of the biggest questions for cities deploying a gunfire detection system is where to place the sensors. The typical goal is to place them somewhere where the city frequently suffers gunfire, they won’t be easily spotted, and can be effectively used without interruption or obstruction. One of the more glaring downfalls of a GDS is the abundancy of sensors needed in order for it to work properly. With a popular GDS known as ‘SECURES,’ the redundancy of the sensors needed with this system pose a very significant disadvantage:

“The system detects potential gunshot signals using a dense grid of "pole units", i.e. a collection of microphones placed on utility poles at every street corner (i.e. about every 500 ft.) in an urban area to be covered. Since this high density grid requires more than 80 sensors per square mile covered, it is very expensive to deploy and maintain (Showen, 1999)”

Cities being faced with this obstacle have to decide as to what area this system will be most effective. It’s highly unlikely (and not very cost-effective) for a city government to deploy this system citywide. Cities are frequently plagued with gunfire within a small area or specific part of town and can localize the deployment of the system in order to allocate their resources most effectively.

**2.2.2. Sensor Deployment**

As mentioned, the locations of these sensors is integral to their reliability and accuracy. In addition to that, cities must be confidential and discrete as to where they place sensors and microphones. In the case where the location of GDS hot spots are publicly disclosed, offenders may choose to purposely avoid firing rounds within view of the GDS. This could also promote the criminals to relocate gun violence to a different area of the city where there previously was less gun-related crime. Keeping sensor deployment locations private is paramount to the success of a gunfire detection system.

***3.0. Reliability and Monitoring of GDS Inputs***

The reliability of sensor monitoring and response is highly dependent on the method of screening these inputs. Depending on the company or organization, some manage false alarms and sensor triggers by manual, human recognition of a shot being fired. Conversely, some depend on automatically comparing the data to previously confirmed gunfire in order to trigger the alarm. While both methods come with some degree of standard error, appropriate training and expansion of the ‘known gunfire’ database can actively improve reliability of gunfire recognition.

**3.1. Manual Assessment and Response**

Human assessment of gunfire incidents seems to be the logical answer to a GDS company’s false alarm problems. But with the manual labor needed and the issue of individual bias, it may not be quite that easy. Manual assessment requires extensive training and a keen ear to be able to properly and effectively recognize gunfire.

**3.1.1. Software**

Most companies involved in this line of work are very discrete with their software preferences when it comes to monitoring a gunfire detection system. One of the most well-known, ShotSpotter, only provides hints as to what software they use and how it is utilized to narrow down incidents. According to their website, “the software filters out ambient background noise, such as traffic or wind, and listens for impulsive sounds characteristic of gunfire” (“ShotSpotter – Technology,” n.d.). Their software can analyze the audio signals, and on a local map, pinpoint the location the sensors believe the shot to have originated. Each company’s ‘brand’ of software is typically proprietary to the company and isn’t used by any other organizations.

**3.1.2. Human Assessment**

Companies like ShotSpotter that typically have algorithms and machine learning to do a majority of the heavy lifting also rely on human analyzation to confirm gunfire. For ShotSpotter, they employ workers in Newark, California to receive and monitor their GDS inputs from around the nation. This adds an additional layer of security and reliability to the process, but also opens up the company to unintended human bias and privacy concerns. ShotSpotter debunks these concerns by referencing their extensive training process:

“ShotSpotter's incident reviewers hear thousands of gunfire incidents during their training, and each incident is presented to them from the perspective of multiple sensors. ShotSpotter incident reviewers have heard and analyzed more acoustic gunfire incidents, from more perspectives, than quite literally anyone else in the world.” (“Community Gunfire Alert,” n.d)

**3.1.3. Decibel Level and Sound Triangulation**

The decibel level and the amount of time it took to be received by the sensors is integral to triangulation of the gunshot. Naturally, sound waves travel outward from the source in a longitudinal pattern at 343 meters per second - or as it’s more commonly known, the speed of sound (Shade, 2012). With sensors being placed a known distance apart and the speed of sound being constant (given the ambient temperature is known), the location of the shot can be accurately approximated. At least three sensors must have heard the shot in order for triangulation to be accurate and the shot to be properly located. Triangulation is a rather popular concept and has been used in many other concentrations; ranging from the military use of radar, to triangulating data in order to validate claims.

**3.2. Automated Assessment and Response**

Some companies opt out of manual assessment and rely on artificial intelligence to confirm gunfire activity. Companies like AmberBox and Shooter Detection Systems choose to deploy sensors that are completely self-reliant and require no human intervention to operate.

**3.2.0. Indoor Sensors**

AmberBox and Shooter Detection Systems like to promote their businesses on the reliability and use of their indoor sensors. The move to indoor sensors for companies like this certainly wasn’t accidental. With school shootings and church massacres on the rise, it’s easy to see why companies are quick to fill the void left by companies that only market outdoor sensor deployment. Most of these indoor systems rely on an automated algorithm to compare the inputs from the sensor to previous confirmed gunfire incidents. Like their outdoor counterparts, indoor sensors use a conjunction of percussion sensors to detect the muzzle blast and shockwave of the bullet, infrared to detect the flash of the muzzle, and microphones to record the incident and use it for immediate comparison. Companies like AmberBox store a high volume of gunshot samples on each sensor itself in order to expedite the comparison process and respond as quickly as possible (Orfandis, n.d.).

**3.2.1. Line of Sight**

A big feature of both indoor and outdoor sensors is the flexibility. The sensors don’t need to “see” the gun being fired in order to confirm shots fired. It can be in the next room, a block over, or deep into the alleyway. Especially true for indoor sensors and their strategic placement, a system not requiring “line of sight” in order to be activated is a crucial feature that many buyers seek out. In addition, outdoor sensors generally don’t require line of sight either. With the abundance of sensors in an area and the quality of the microphones used this allows for the company (and law enforcement) to receive more complete, reliable information when confirmation of a fired gunshot is needed. Considering sound degrades over distance and the effect of “bouncing” off the walls, employees (and A.I. also learning how to properly classify gunfire) must use caution when confirming a shot fired. Often, they are able to receive a sound clip from multiple locations which allows them to better analyze the shot.

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*Figure 2 (Right) – An example of an indoor sensor used by the company AmberBox. This detector receives multiple sensor inputs and compares it to known shot data contained within each device.*

**3.3. Confirmation of Gunfire Activity**

How does it know? In order for Gunfire Detection companies to be considered reliable, they must be able to filter out sounds and events that mimic the sound of gunfire. How useful would a system be if it prompted a city-wide response from law enforcement over a teenager throwing a firecracker? Though no employee or “artificial employee” are ever perfect, these companies have nearly perfected different methods of combatting false alarms from their systems and sensors.

**3.3.1. Comparison of Known Gunfire**

The most common method of confirming a gunshot is by comparing the sound clip and other inputs to a sample that knowingly represents gunfire. Doing this, employees and automated systems can compare audio signatures that are specific to the discharge of a firearm. For indoor systems, this is often the first and last step. Indoor sensors can typically receive clearer and more defined audio than those used outside. Confined within a building’s walls, sound degradation is more contained, and the clips received aren’t drowned out by city noise pollution. Without human intervention, indoor sensors can typically respond and dispatch local authorities in under 30 seconds. In fact, companies like AmberBox advertise their automated system to be able to listen and respond to a gunfire incident in an average of 3.6 seconds (Orfandis, n.d.).

*****Figure 3 – An analyzation of a typical gunshot recorded by a microphone. This is a specialized depiction as it’s able to discern and present the individual flashes and the difference in sound provided by each.*

**3.3.2. Muzzle Flash**

One of the most distinct and unique signatures of a gunshot is the muzzle flash it produces as the bullet is fired. When a firearm is first fired, muzzle glow will precede the bullet. This is due to superheated gases escaping by the bullet before it is expelled, thus creating a red aura around the front of the barrel. This is followed by the primary flash, which is caused by propellant gases exiting the firearm behind the bullet. This is the brightest and hottest flash of the sequence. Following this is another quick flash called the intermediate flash, which is caused by the bullet breaking the sound barrier and creating a red disc in front of the barrel. Lastly is the secondary flash, which is seen farthest form the muzzle. This flash is caused by the mixture of fuel-rich gases and oxygen in the atmosphere surrounding the muzzle. Any unburnt powder or other heated materials are then ejected as sparks (Glasco, 2014). All of the characteristics of a gunshot listed above can be picked up by infrared sensors and can be the employee’s (or algorithm’s) tell-tale sign of true gunfire.

**3.3.3. Bullet Shockwave**

Another helpful tool that helps responders verify gunfire is the shockwave of a bullet. A bullet breaking the sound barrier creates a very distinctive “crack” and can also be picked up by nearby sensors. When a bullet goes supersonic it carries a few known characteristics. The bullet will create a curved barrier at the front of the bullet which carries the “shock wave”, followed by its ripple effect of traveling through the air. Left in the bullet’s wake is a trail of turbulence. Similar to a plane passing by at supersonic speeds, the shockwave follows the bullet and can be physically felt on its way by if the force is strong enough. Due to the unique qualities of this type of event, this signature is increasingly hard to replicate. The inclusion of this input is one of the key factors of being able to determine the difference between a car backfiring on its way by and a true gunfire related incident. To the human ear, gunfire may “sound” the same as a firecracker, but on paper and given in wave form, it paints a much different and definitive picture.

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*Figure 4 – A bullet traveling through the air at supersonic speeds. A shockwave precedes the bullet and it’s followed by a trail of turbulence.*

***4.0. Government Use of Gunfire Detection Systems***

The use of Gunfire Detection Systems within the U.S. government has been constant throughout the past. From detecting sniper fire in World Wars to listening for artillery, government advances in the space have continually ramped up the features and wide-spread use of Gunfire Detection Systems.

**4.1. Military Use and the Adaptation to Urban Environments**

The military has used Gunfire Detection through many years and many wars. From sound ranging of artillery sites, to a system optimized for use with moving vehicles and sniper fire. In the military, there exists a variant of a typical GDS. The United States army used a system called “Boomerang” created by Raytheon technologies. This technology is used either in a stationary position or on a moving vehicle, such as a Humvee. The GDS listens for gunfire passing by the sensor, mainly listening for the bullet’s shockwave. When a shot is detected, it can audibly shout the marked position of the shot – “Shot. Two o’clock. 400 meters.” The military-grade version can also filter out shots being fired by soldiers from the Humvee or the site itself. The GDS is also highly resistant to false alarms caused by bumps, door slams, and wind noise (“Raytheon: Boomerang III”, n.d.). Boomerang has been in use in the Military setting for many years and has seen many positive improvements and re-launches. With the use of Boomerang came the eventual adaptation to use within urban environments. The system saw a few tweaks before the concept was deployed on cities across America. Namely, adaptations to how and when it alerts to gunfire and the method of response to that gunfire. Urban deployments detect gunfire from any source, regardless of distance, and don’t filter out those that are closer in proximity to the sensors. They are better adapted to filter out city noises (backfire, fireworks, etc.) instead of distractions that would only be found on the battlefield. Lastly, they report the gunfire incident differently. Most systems deployed in a city report to a graphical user interface at some central location. This allows for mediation of the gunfire before dispatch as well as a single, convenient place for all alerts to aggregate.

**4.2. Funding and Cost of a Gunfire Detection System**

The cost of a Gunfire Detection System can depend on a multitude of factors. One of the main deterrents of implementing a Gunfire Detection System in a city is the cost and upkeep associated with its use. For a typical system (still covering only a couple miles) the number of sensors can easily reach 200+. With each sensor containing its own hub of electronics and sensors, each sensor (multiplied by 200+) can quickly become very expensive for a city government. On average, including upkeep and monitoring by the company, a company like ShotSpotter will charge between $65,000 and $90,000 per square mile per year (Drange, 2016). At this rate – unless they’re seeing superior return and spike in arrests for gun crime – ShotSpotter could prove to be quite a gamble. For a booming metropolitan area like San Antonio, even deploying the system in a small subset of the city cost taxpayers nearly $270,000 to implement. The funding for projects like this often stems from grants and donations from the public, but the funds are primarily drawn from taxes paid to the city.

***5.0. Success and Failure of Gunfire Detection Systems***

Although they seem universally beneficial, Gunfire Detection Systems have seen a healthy amount of pushback from the public. Some will never receive funding. Some cities dedication to the technology have come and gone. With a system like this, there is bound to be both positive and negative experiences. For the most part, cities see an uptick in arrest rates for gunfire related crime, as well as faster response time by law enforcement. While on the other hand some cities have complained of constant false alarms, arriving to a scene to find no evidence of shots fired, or responding to more dead-end calls than before the system was implemented.

***5.1. SENTRI***

SENTRI was one of the earlier Gunfire Detection Systems that was deployed to the public. SENTRI used common inputs used with other GDS’s, but in a slightly modified way. SENTRI was primarily microphones and cameras on a lamp post. When a shot was heard or what they thought to be a shot was heard, the mounted cameras would pan to that direction and zoom in on the location of the “shot.” As you can imagine, this system saw a lot of drawbacks. One of the most glaring was the use of the cameras to try and capture footage of the shooter. The cameras delayed in response, would often be blocked by foliage or cars/objects on the street, and provided a very grainy image of the shooter or location of the shots.

**5.1.1. SENTRI: Delaware**

One of the largest blunders by the company was its implementation in Delaware. A $250,000 grant was used in one of Delaware’s most populous cities to implement the Sensor Enabled Neural Threat Recognition and Identification system, also known as SENTRI. After 18 sound-sensing cameras were installed across the metro, the system failed to bear fruit. In an unprecedented period of violence where the city saw roughly 600 reported “shots fired” calls and 175 shootings, SENTRI detected only “5 or 6” gunfire incidences. Of those, only one incident caused the cameras to be activated and pointed in the corresponding direction. In this case, foliage vas in view of the camera and blocked any usable angle of the shooter.

**5.2. ShotSpotter**

Like SENTRI, ShotSpotter has seen both ups and downs to their Detection System. In the Delaware case, after noticing how ineffective SENTRI is for them, the city of Wilmington opted into a new and improved GDS – ShotSpotter. ShotSpotter has proven to be the dominant name in Gunfire Detection - but it doesn’t come without faults. In Fall River Massachusetts, the police chief and city officials agreed to quickly put an end to ShotSpotter. According to them, ShotSpotter only worked “less than 50% of the time.” Fall River, Massachusetts news coverage said:

“Dupere said last summer that ShotSpotter had reported too many false alarms of gunfire while missing actual shots-fired incidents in Fall River. Dupere said then that he and other city officials decided the money would be better used to expand the police department's video surveillance system in the city (Fraga, 2018).”

Faced with these statistics, some cities are finding it hard to gamble so heavily on ShotSpotter.

**5.2.1. ShotSpotter: Nebraska vs. Hill**

The reliability of ShotSpotter data has been widely questioned since inception. It’s (sometimes) useful to locate a criminal or shots being fired, but would the data collected hold up in a court of law? A prominent case involving the use of ShotSpotter data was debated in Nebraska in 2014. The reliability and accuracy of the sensors was quickly called into question:

“The sensors self-calibrate every 48 hours, and if a sensor does not self-calibrate, SST is automatically notified. In addition, each sensor sends a “heartbeat pulse” once every 30 seconds. In fact, each GPS sensor, as well as each of the four microphones attached to it, independently communicates with the ShotSpotter server about its health (State of Nebraska v. Thylun M Hill, 2018).”

The data and evidence provided by the ShotSpotter sensors and Incident Review Team proved to be sufficient for the courtroom. Almost all aspects of the reliability and methods of ShotSpotter were speculated upon, and the facts prevailed. This turned out to be a big stepping stone for the company and proved that their system can be a pivotal (and reliable) factor in putting criminals away for their crimes.

**5.2.2. Abandonment of ShotSpotter**

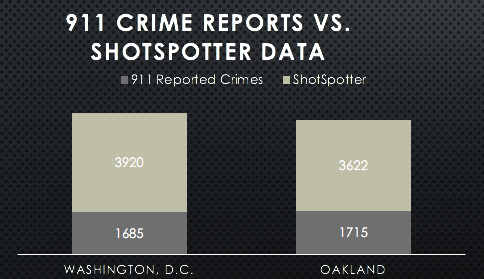
Not all reviews of ShotSpotter are gleaming and positive. ShotSpotter has its drawbacks and limitations, just like any other system of this kind. Some populations had such negative reviews of ShotSpotter that they either voted to axe the contract at the end of the scheduled time, or to cut off the agreement prematurely. In Charlotte, North Carolina, the mood towards ShotSpotter wasn’t very upbeat. Law enforcement lost trust in the system, and they were quickly spending more time chasing down rogue alerts. Aside from this, ShotSpotter was only able to locate about 1 out of 41 incidents in Charlotte. “The $160,000 that was used to fund ShotSpotter would be better used for street-level crime cameras, Real Time Crime Center technology and body cameras (Wootson, 2016).” Cities like Oakland, Fall River, Massachusetts and Suffolk County, New York soon followed suit.

***6.0. Traditional Gunfire Reporting***

Traditional reporting of gunfire prior to ShotSpotter is and was pretty limited. Law enforcement agencies primarily rely on calls from citizens and their ability to accurately recall and recite what they saw. Though this may seem foolproof, everyday citizens are usually unreliable in their eyewitness testimony. Furthermore, some members of the community are reluctant to share information with law enforcement. Gunfire related crime is notorious for being underreported amongst U.S. communities. Whether this is due to the caller being unsure of what they heard, community members being reluctant to trust law enforcement, or communities becoming “numb” to the constant gunfire, it becomes hard to pinpoint the driving cause behind this discrepancy.

**6.1. ShotSpotter study of Washington D.C. and Oakland**

In April of 2016, respected professors Jennifer Doleac and Jillian Carr performed an extensive study on the underreporting of gun violence in our communities. The study focused on Washington D.C. and Oakland, California. A glaring point of the study was the comparison of ShotSpotter recorded data to the data provided by the local police departments. Year after year, ShotSpotter consistently outnumbered the amount of calls by community members and reported a significantly higher amount of shots fired incidents. According to the study, “In DC, only 12.4% of gunfire incidents result in a 911 call to report shots fired (Carr, 2016).” With that low of a statistic, it’s imperative that local law enforcement approach the issue from multiple different angles. With the installation of ShotSpotter in these areas, the statistics changed significantly. While civilian reporting remained stagnant, the high number of reports by ShotSpotter showed a significant contrast. In 2011 ShotSpotter reported 3920 incidents in the Washington D.C. area. During that same year, the local police department heard only 1685 calls from concerned citizens.



**6.2. Civilian Reliability and Underreporting**

When it comes to an eyewitness, recounted stories are often a stretched truth. During stressful incidents it becomes tougher and tougher to recall directions and specifics of an encounter. The same is true for those that are a witness or victim of gunfire. Human psychology shows that humans are susceptible to ‘reconstructive memory’ where we put together bits and pieces of a story that align with our individual belief and interpretation – not necessarily on unbiased fact. These half-memories are “therefore capable of distorting unfamiliar or unconsciously ‘unacceptable’ information in order to ‘fit in’ with our existing knowledge or schemas.  This can, therefore, result in unreliable eyewitness testimony (McLeod, 2009).” Furthermore, for reasons that remain unknown, citizens are consistently underreporting the violence going on within their communities. Although it varies greatly based on location, the reporting of gunfire related crimes is consistently within range of 20%-40%. In an Oakland area “patrolled” by ShotSpotter, “the system documented 258 reports of gunfire across East and West Oakland - the two areas blanketed with sensors. During that period, residents called in 197 reports of gunfire, according to police data (Kane, 2014) .” So even if a civilian happens to call about a gunfire related incident, it’s unlikely that law enforcement will obtain an arrest based only on the report from the caller.

***7.0. The Effect of Gunfire Detection Systems on Law Enforcement***

Gunfire Detection Systems aren’t all upsides for law enforcement. With new technology comes growing pains, and the agency will have to learn to deal with alerts from the GDS, both real or artificial. For some agencies, the use of a GDS proved ineffective and counterproductive to their workloads and response times.

**7.1. Response Times**

The response time of a law enforcement agency is a crucial statistic. A delay of only a few seconds could be the difference between life and death for some callers. When it comes to Gunfire Detection Systems, the response is mostly positive. But using a GDS technology named SECURES, the National Institute of Justice performed a study on data provided by their reporting system. During the test period, “the mean response time to citizen-generated reports of gunfire during the test period (about 30 minutes) was about 30 percent less than the mean response time to technology-generated reports (about 45 minutes) (Mazerolle, 1998).” This could be due to a number of factors. Police may not take these types of alerts as seriously, or they believe it would’ve been corroborated by a call had it been true gunfire. Regardless, this shows the implementation of a GDS inadvertently affects the response time of law enforcement officers.

**7.2. False Alarms**

Many of the Gunfire Detection Systems in deployment today are susceptible to a number of faults. One of the main ones affecting them are false alarms. This doesn’t just prove to be an annoyance for the company weeding out these false alarms, but the law enforcement agencies actively responding to them. No review center is perfect, and every AI has its limitations – so a number of false alarms are bound to fall through the cracks. This can be a burden and a resource waster for law enforcement agencies, and their inattention to other civil needs may prove the system to be dead weight to them. Also included in the report regarding SECURES was a reflection of the system’s abilities and its effect on police workloads:

“During the trial period, police were dispatched to 151 random gunfire events identified only by SECURES and to 39 events identified by citizens (some of which were corroborated by SECURES). The extra 151 SECURES dispatched events (in addition to the 39 citizen-identified dispatched events) represent a 287-percent increase in the number of police dispatches to random gunfire problems (Mazerolle, 1998).”

Though this 287% uptick in “random gunfire problems” is unlikely 100% due to realistic gunfire. Police time and resources can quickly be wasted away on chasing down dead ends and false alarms – and the Police Chief and the tax-paying public aren’t very fond of that.

***8.0. Conclusion***

Gunfire related crime is an epidemic that continues to ravage through our community streets. Day in and day out innocent lives are taken due to the unregulated nature of gunfire within city limits. Police officers and law-abiding citizens are becoming increasingly pressured to make sustainable changes to our infrastructure in order to combat this type of rising crime. At this time, Gunfire Detection Systems are only in a stage of infancy. Despite the current drawbacks of these systems, I believe with optimization and continuous updates to methods of inputting and reporting, these systems can become more reliable and commonplace than ever before. With a steady stream of competitors joining the market it’s inevitable that the astounding price of these systems will gradually be driven down. Companies like ShotSpotter and Amber Box are constantly innovating, and the future of gunfire detection is on the horizon. Due to the large discrepancy in ShotSpotter confirmed reports and citizen call-ins, it would be ideal for citizen reporting of gunfire to eventually become obsolete. Along with the development of smart cities, technology like ShotSpotter could blanket entire metropolitan areas with automated reporting. Response times and workload on police could be minimized, and overall community trust of law enforcement could see a positive boost. Despite the cost of Gunfire Detection Systems, it’s become a necessary step in some areas in order to take appropriate action to stop the continuous growth of gun violence. In areas with less concentrated gun violence or too large an area to cover with a GDS, they may not see the entirety of the benefits a GDS has to offer.

With the unfortunate increase in school and workplace shootings, indoor sensors have also become common and beneficial. Companies and school districts are implementing them in public areas and hallways as the need to protect your employees and children becomes more and more of an everyday necessity. They’ve evolved to work almost immediately and automatically and can even lock specific doors and entrances when the alarm has been tripped. With the rigorous advancements in this field year after year, I believe it’s only a matter of time before every school and community is protected by a Gunfire Detection System.

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