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Predicting the Likelihood of Mass Shootings in a Location Using Prominent Risk Factors

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Introduction

Mass shootings are incidents in which 4 or more casualties - injuries or deaths - have occurred due to gun violence. If the shooting has 4 or more deaths, then it is considered a major mass shooting. These mass shootings have become a significant problem in the United States in the past few years with over 600 incidents in just 2022, resulting in over 700 deaths and around 3000 injuries (Gun Violence Archive, 2023). Additionally, in the first 4 months of 2023, over 150 mass shootings have happened in the United States at a rate of about 1.5 shootings per day (Gun Violence Archive, 2023). Despite the largely frequent occurrences of these shootings in American society, the government has taken very little action to prevent these mass shootings from occurring. While part of this is because of the widely varying ideals on gun control on the different sides of the political spectrum (Braga, 2001), a large part of this inaction is also due to the unpredictability of these mass shootings (Duwe et al., 2022). Even though mass shootings happen quite often, they are erratic in their nature which makes it hard to observe patterns among them. However, if someone were to create a way to easily predict the odds of the occurrence of these mass shootings using certain factors that are noticeable, this could allow the public to understand apparent patterns in mass shooting occurrence and help the government create legislation to help prevent future mass shootings. Thus, this study aims to develop a predictive model to assess the likelihood of mass shootings based on key socio-economic and geographic factors. By identifying high-risk cities, this model could provide policymakers with tools to implement targeted preventive measures. To approach this serious topic of mass shootings and learn more about these potential factors, the history of these shootings must first be examined.

Literature Review

The Past

Various definitions for mass shootings have been used throughout the past few decades such as the one established in the Assistance for Violent Crimes Act of 2012 which states that a mass shooting is a shooting in which 3 or more people have been killed (Booty et al., 2019). However, the most common definition today, established by the FBI, is a shooting incident in which 4 or more people have been killed, not including the perpetrator (Booty et al., 2019). Over the past 50 years, an average of 28 mass shootings have occurred yearly (Duwe et al., 2022). The only year without a mass shooting in these years was 1979 (Duwe et al., 2022). There are several types of mass shootings, the most common of which are familicide, felony-related, or crime-related, (Smart & Schell, 2021) with around 75% of the mass shootings being these types (Duwe et al., 2022). However, the most dangerous and most reported upon mass shootings are public mass shootings, which especially became prevalent in the 90s with cases such as the Columbine High School shooting and the Westside Middle School shooting (Fox & Harding, 2005). Despite increases in mass shootings in the 80s and 90s, little research was done about them, with only 48 articles compared to the over 11,000 there are today (Fox & Levin, 2021). This led to authorities dismissing cases as a product of mental illness and moving on, especially since an emphasis on mental health was not placed at this time (Fox & Harding, 2005). While research on these incidents has significantly increased since then, the effort put in to prevent them has not. From 2000 to the early 2010s, 160 active shooter incidents occurred with 1043 casualties, with the number of incidents increasing throughout the years (McCarthy, 2014). Among the worst of these incidents include the Aurora Cinemark shooting with 12 killed and 58 injured, the Virginia Polytech Institute shooting with 32 killed and 17 injured, and the Sandy Hook Elementary shooting with 27 killed and 2 injured (Blair & Schwieit, 2013). Not only were these incidents becoming more numerous, but also more dangerous as well. While the years 2000 to 2006 had an average of 6.4 public incidents a year, 2007 to 2013 had an average of 16.4 (Blair & Schwieit, 2013). Unless something is changed or proper action is taken, these shooting incidents will continue to occur at increasing rates.

The Present

Mass shootings continue to occur in our present and seem to have become both more frequent and deadly. In 2015, about 370 Americans were killed in mass shootings (Santilli et al., 2017). There is 1 major incident for every 14 million people in the country and 1 resulting death for every 4 million people (Smart & Schell, 2021). This accounts for approximately 0.8% of all homicides and approximately 0.4% of all firearm deaths (Smart & Schell, 2021). In 2017, the deadliest mass shooting of all time occurred in Las Vegas which accounted for over half of all public mass shooting fatalities and injuries that year (Smart & Schell, 2021). Within the next 3 years, the rate at which mass shootings occurred had tripled (Zakopoulos et al. 2022). In 2019, there were a total of 417 mass shootings (both public and private), with states such as California, Illinois, Texas, Louisiana, and Maryland having the most (Sen-Crowe et al. 2021).

Despite the COVID-19 pandemic forcing people to stay inside for the majority of the next year, the number of mass shootings in 2020 increased to 611 (Zakopoulos et al. 2022), with states such as Illinois, California, New York, Texas, and Pennsylvania having the most (Sen-Crowe et al. 2021). Not only are these shootings hurting communities physically and mentally, but also financially as well with “the estimated cost of firearm-related injuries [exceeding] 1 billion dollars per year” (Sen-Crowe et al. 2021). This shows that the problem of mass shootings will continue to worsen unless action is taken. However, action cannot be taken unless the proper risk factors of these mass shootings are considered.

Sociodemographic & Socioeconomic Factors

Many risk factors are prevalent in the occurrences of mass shootings but some of the most blamed ones are sociodemographic factors. One interesting thing to note about mass shootings is that only 3.8% of shooters were female while the others 96.2% were male (Blair & Schwieit, 2013). This could mean those areas where the male population is much more prevalent than the female population could be at higher risk for a mass shooting, or this could simply be due to men being more likely to own a gun. Along with this, despite people of color being much more likely to experience gun violence (Santilli et al. 2017), shooters in mass shootings are much more likely to be white than any other race (Smart & Schell, 2021), but as with gender, this is not a guaranteed risk factor as it could be due to gun ownership rates. Looking at those gun ownership rates, a correlation with firearm-related murder rates exists which means ownership rates are a potential risk factor for mass shootings (Lin et al. 2018). The most common age range for shooters happens to be 20-29 years old and about 84% of them were younger than 45 which is surprising considering that the average age range for gun owners is 35-54 years old (Smart & Schell, 2021). Another risk factor to look at is the age demographics of the area though this likely plays a minor role in the overall risk of a shooting. It was also found that lower high school graduation rates correlated with a higher likelihood of a mass shooting (Kwon & Cabrera, 2019). As mentioned previously, mental health issues are often blamed for mass shootings. Recent studies have shown that this could be true as the likelihood of committing violence is greater for those with major mental illnesses such as severe depression or schizophrenia (Philpott-Jones, 2018). While about 62% of shooters have had some mental health stressors (Bast & DeSimone, 2019), only 8% of mass shooters exhibited symptoms of serious mental illness that can be linked with aggression (Fox & Levin, 2021). Due to the variability of mental health and illness among these incidents, mental illness cannot be relied on as a risk factor without further research. Along with several sociodemographic risk factors, the socioeconomic risk factors of mass shootings seem to be good predictors of mass shootings. Despite violence rates being higher in low-income neighborhoods (Santilli et al. 2017), when it comes to poverty and mass shootings, there is no significant correlation (Kwon & Cabrera, 2019). However, when it comes to income inequality in an area, it was found that it significantly increases the likelihood of incidence of mass shootings in that area (Kwon & Cabrera, 2019). In fact, "Gun violence disproportionately occurs in communities experiencing social and economic inequalities", which shows that income inequality in an area can be considered a major risk factor for mass shootings (Santilli et al. 2017). Along with the socioeconomic factors of the people living in the area, another factor to consider is the purchase of guns at both dealerships and gun shows, which are the most common places to buy a firearm.

Location-Based Factors

There have been links found in previous studies between the number of gun stores in an area and the occurrence of gun violence, but the majority of these deaths were suicides (Zakopoulos et al., 2022). When comparing firearm dealership locations within 50 miles of major U.S. mass shootings from 2010 to 2020 with the locations for the entire country, it was found that of all the dealerships in the country, 28.1% of them were within 50 miles of the 67 major mass shootings that occurred (Zakopoulos et al., 2022). When looking at the density of these dealerships, there were 0.03 dealerships per square mile in areas within 50 miles of mass shootings which is actually 62.7% times higher than the national average (Zakopoulos et al., 2022). When it comes to gun shows, obtaining a firearm is much easier than normal due to low restrictions on purchases and this may result in firearms falling into the wrong hands (Duggan et al. 2011). However, when examining the relationship between gun shows and mass shootings, there seems to be no correlation (Duggan et al. 2011). The reason for this may be due to the limited nature of gun shows as these typically only last a few days, while a dealership is usually a permanent location (Duggan et al. 2011). While gun shows are not a risk factor because of their time restrictions, gun dealership locations can be seen to be a major risk factor. This is a problem since some areas have more gun dealerships than they do common commercial retailers (Zakopoulos et al., 2022). While most private mass shootings happen in residential areas, 45.6% of public mass shootings occur in commercial areas (Blair & Schwieit, 2013) such as offices, factories, grocery stores, theaters, and many more locations (McCarthy, 2014). Another 24.4% occurred in educational areas such as schools or colleges, with schools being much more likely than colleges to have a shooting (Blair & Schwieit, 2013). Schools in rural areas also happen to have a higher chance of a shooting occurring than schools in urban areas (Fox & Harding, 2005). Along with that, high schools have a higher risk than elementary or middle schools (Blair & Schwieit, 2013). These areas are much more likely to be at risk for shootings than other areas such as government property or places of worship (Blair & Schwieit, 2013). Therefore, larger commercial and educational districts in an area should be considered a risk factor for the likelihood of mass shootings. Even if not directly at an educational facility, a location's proximity to schools could be used as a predictor of mass shootings as well, as the average distance from a mass shooting to the nearest school ranged from 0.16 to 3.04 miles (Sen-Crowe et al. 2021). However, proximity to a school may not be as accurate of a predictor as the percentage of an area covered by educational districts. Lastly, there is also the contagion effect which makes a shooting much more likely to happen near another shooting (Lin et al. 2018). However, this effect is temporary so while there is a connection between the contagion effect and mass shootings, it cannot significantly predict the mass shooting incident rates past a certain amount of time (Lin et al. 2018).

Legislative Factors

There is also the matter of gun laws differing among states. It seems that mass shootings mostly occur in the West and especially the South, which happens to have much looser gun laws and higher gun ownership than in other areas (Fox & Levin, 2021). A 10% increase in the permissiveness of gun laws in a state correlated to a 9% increase in the rate of mass shootings in a state (Reeping et al. 2019). Along with that, with more permissive gun laws comes more gun ownership and it was seen that a 10% increase in gun ownership comes with a 35% higher rate of mass shootings (Reeping et al. 2019). More restrictive states tend to have much lower chances of having a mass shooting which means that gun laws can be seen as a significant risk factor (Reeping et al. 2019).

The Future

When it comes to the future and the possibility of mass shootings, nothing can be said for sure due to its unpredictable nature (Duwe et al., 2022). The only predictions that have been made about future incidents are the possibility of a shooting occurring at the severity of the 2017 Las Vegas shooting, which would be about 35% in a 5-year interval (Duwe et al., 2022). Other than this, not much work has been done on predicting mass shootings mostly due to the various complicated factors behind them. The reason for this is that previous models have failed to consider integrating these factors into a cohesive predictive framework. While it may not be possible to predict exactly when and where the next mass shooting will happen, it should be possible to predict the likelihood of mass shootings in an area given all the previously mentioned risk factors that have been observed by many researchers. To fill this gap in current mass shooting research, the goal of this project is to create an algorithm that can accurately predict mass shooting locations and show locations that are at risk of shootings based on factors of the area that are commonly associated with shootings.

Methods

This research involved a predictive modeling method through a mathematical algorithm in order to predict the likelihood of a mass shooting occurring within a year's time. Since this project mainly involves data analysis and mathematical modeling, it involves no apparent risks. However, due to the potentially disturbing nature of the topic, it may lead to discomfort due to the research involved on previous mass shootings.

From January 2023 to the end of February 2023, the method was carried out using a computer with access to the internet in order to collect miscellaneous data, spreadsheet software in order to keep track of all data and for using and creating the algorithm, 2020 U.S. Census data for the 100 most populated cities, mapping software (Google Maps), gun ownership data from RAND Corporation, income inequality ratios from the Economic Policy Institute, and also information on previous mass shootings from the Gun Violence Archive.

Firstly, the 100 most populated cities in the U.S. were found using the 2020 United States Census data. The reason that only the top 100 cities were observed was due to the limitation of both time and data. Much of the data needed was not available on public databases so a portion of the data had to be hand-collected/calculated. This necessity to hand-collect data made data collection a tedious task which is also why the method was limited to 100 cities.

Next, the weightage of each of the 8 different risk factors was determined based on how strong their correlations to mass shooting occurrence were. Research by Kwon and Cabera (2019) shows that lower graduation rates are linked to a higher likelihood of mass shooting occurrence thus allowing graduation rates to be considered a risk factor. In research done by Reeping et al. (2019), it was found that that an increase in gun ownership leads to a rise in mass shooting occurrences along with an increase in gun law severity leading to a decrease in mass shooting occurrences leading to gun ownership rates and gun law severity being considered as risk factors. Higher rates of income inequality were shown, by research from Santilli et al. (2017), to lead to an increase in mass shooting occurrence thus allowing income inequality rates to be considered as a risk factor. Research by Blair & Schwieit (2013) has shown that the area density of commercial locations and education facilities both led to increases in mass shooting occurrence as each density increased, allowing for the consideration of the area density of educational facilities and commercial locations as risk factors. Proximity to previous mass shootings was found from research by Lin et al. (2018) to have a link with mass shooting occurrence, with a closer proximity meaning a slight increase in mass shooting occurrence, allowing for it to be considered a risk factor. Finally, gun dealership density in an area was found by research by Zakopoulos et al. (2022) to lead to an increase in mass shooting occurrences as it increases, leading to it also being considered a risk factor. The strength of correlation used to weigh each factor was determined by looking at the many different studies that considered how these factors affected mass shootings. If a correlation for a certain factor was described as existing but not the strongest indicator among the sources, it would be weighed at either 4 or 6. Educational area density and high school graduation rates were both weighed at 4 as they were described as having a decent correlation though not completely strong. Gun ownership rates and commercial area density were weighted at 6 points as they were also not completely strong but still described as stronger than factors weighted at 4 points. The four other factors were weighted at a value of 10 points as these were shown to strongly correlate to the occurrence of mass shootings according to the reviewed sources. However, it is important to note the limitation that statistical validation of these weightage values is not possible at this stage and will require future research.

Next, the 8 risk factors were collected through varying methods. High School graduation rates were collected through the websites of school districts in each city. If multiple school districts were prominent in a city, the graduation rates were averaged. Gun ownership rates by state can be collected from the RAND Corporation. The gun ownership rates were collected by state rather than city as data for this factor was not available by city. Income Inequality ratios were collected from the Economic Policy Institute. These ratios are the average income of the top 1% in a city divided by the average income of the bottom 99% in the same city. The area density of both educational facilities and commercial places were both calculated separately by taking the amount of them in a city (schools and colleges for educational facilities & malls and shopping centers for commercial places) and dividing it by the area in square miles of the city. The density of gun dealerships was found in a similar matter to education and commercial area density as it was found by getting the number of dealerships in the area and then dividing it by the area, in square miles, of the city. These 3 factors all had to be hand-calculated, as the data for them was not online. To find the number of each type of facility in a city, each facility was also hand-counted through the use of Google Maps. Proximity to a previous mass shooting was calculated by taking all major mass shootings within the past 5 years that fit the FBI's definition (4 or more killed), placing them on a map, and for each city, finding the closest shooting on the map, and measuring the distance in miles between the two cities. Gun law severity was found by looking at each state's laws and evaluating them qualitatively to determine how strict they are. These were then assigned integer values from 1-10 based on strictness.

Once all data for the factors were collected and placed on a spreadsheet, the formula:

$$Factor\ Points\ = \frac{(Factor\ Value\ of\ City - Lowest\ Factor\ Value\ of\ All\ Cities) * (Max\ Points\ Based\ on\ Weightage - 1)}{(Highest\ Factor\ Value\ of\ All\ Cities - Lowest\ Factor\ Value\ of\ All\ Cities) + 1}$$

was used in order to convert the data into its new weighted form. Both graduation rates and proximity to mass shootings were put through the equation twice, once with the highest and lowest factor values of all cities switched and then once regularly. This was to account for the fact that lower values mean a higher risk from these factors.

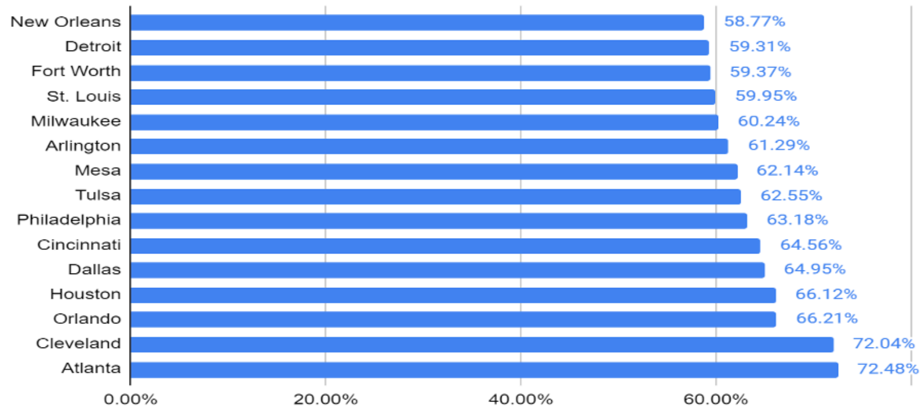
Finally, all of the newly weighted factor values for a city were summed, except for gun law severity, which was then subtracted from the total. This total was then divided by 50, the maximum number of points that could be earned. The resulting value then gives the probability of a mass shooting occurring in the city.

Later, for further analysis, common high-scoring factors among high-risk cities were found and common-low scoring factors among low-risk cities were found. Error and p-values were not calculated due to a lack of post-method data. In order to cross-examine the algorithm's resulting data to determine accuracy, a year's worth of data is necessary. Instead, all mass shootings in the top 100 most populated cities, from the end of the algorithm creation (February 18th, 2023) to April 19th, 2023 were noted and compared with the algorithm's predicted likelihood of shooting occurrence for each of these cities that have had a shooting occur.

Results and Conclusion

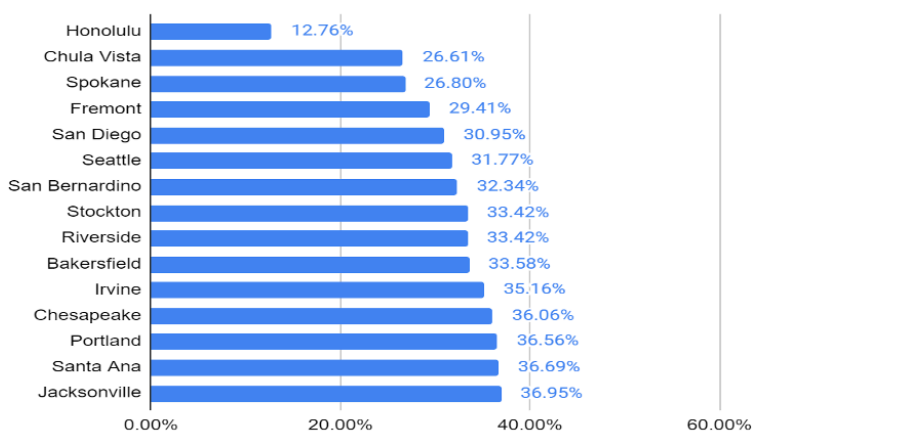
After successfully creating the mathematical algorithm based on the data found for each individual factor and using it to find the probabilities of mass shooting occurrence for the 100 most populated cities in the United States, it was found that Atlanta, Georgia was at the most risk of a mass shooting at a 72.48% chance. The next 4 cities at the most risk were Cleveland, Ohio at 72.04%; Orlando, Florida at 66.21%; Houston, Texas at 66.12%; Dallas, Texas at 64.95%. Other cities at major risk included: Cincinnati, Ohio; Philadelphia, Pennsylvania; Tulsa, Oklahoma; Mesa, Arizona; and Arlington, Texas. The post-algorithm data for these high-risk cities is shown below:

2021 rank	City	State[c]	2021 estimate	High School Gra	Gun Ownership	Income Inequalit	Area Density of I	Area Density of	Proximity to Pre	Density of Gun I	Gun Law Severi	Final Score	Probability
50	Arlington	Texas	392,786	1.13	3.88	5.54	1.86	4.08	8.46	6.69	1	30.64	61.29%
36	Mesa	Arizona	509,475	2.30	4.46	4.94	1.91	4.24	9.88	4.33	1	31.07	62.14%
47	Tulsa	Oklahoma	411,401	2.17	5.23	3.92	1.42	2.32	10.00	7.22	1	31.27	62.55%
6	Philadelphia	Pennsylvania	1,576,251	2.43	4.94	4.37	3.81	4.58	9.01	8.44	6	31.59	63.18%
65	Cincinnati	Ohio	308,935	2.30	4.17	3.83	3.27	4.42	10.00	7.28	3	32.28	64.56%
9	Dallas	Texas	1,288,457	3.22	3.88	6.34	1.79	1.59	8.53	8.13	1	32.48	64.95%
4	Houston	Texas	2,288,250	2.96	3.88	5.56	2.08	2.78	8.71	8.09	1	33.06	66.12%
63	Orlando	Florida	309,154	1.78	3.10	5.58	2.90	4.70	9.04	10.00	4	33.11	66.21%
54	Cleveland	Ohio	367,991	3.48	3.79	4.67	2.95	6.00	8.62	9.52	3	36.02	72.04%
38	Atlanta	Georgia	496,461	1.39	4.08	5.18	2.63	4.10	10.00	9.85	1	36.24	72.48%



It was also found that Honolulu, Hawaii was at the least risk with a 12.76% chance of a mass shooting occurring. The next 4 safest cities were Chula Vista, California at 26.61%; Spokane, Washington at 26.80%; Fremont, California at 29.41%; San Diego at 30.95%. Other low-risk cities included: Seattle, Washington; San Bernardino, California; Stockton, California; Riverside, California; and Bakersfield, California. The post-algorithm data for these low-risk cities is shown below:

2021 rank	City	State[c]	2021 estimate	High School Gra	Gun Ownership	Income Inequalit	Area Density of I	Area Density of	Proximity to Pre	Density of Gun [	Gun Law Severi	Final Score	Probability
56	Honolulu	Hawaii	345,510	1.52	1.00	1.96	2.54	3.66	1.00	3.70	9	6.37914489	12.76%
77	Chula Vista	California	277,220	2.17	2.00	4.91	2.25	1.04	8.86	2.07	10	13.30627805	26.61%
96	Spokane	Washington	229,071	3.22	3.88	3.50	2.57	3.08	1.00	4.15	8	13.3978143	26.80%
97	Fremont	California	227,514	1.65	2.00	3.62	1.90	4.34	9.81	1.39	10	14.70703775	29.41%
8	San Diego	California	1,381,611	2.30	2.00	4.91	1.79	2.90	8.94	2.62	10	15.47478296	30.95%
18	Seattle	Washington	733,919	1.39	3.60	5.76	2.92	3.62	1.28	5.32	8	15.88336891	31.77%
100	San Bernardino	California	222,203	2.83	2.00	2.17	2.16	4.68	9.48	2.84	10	16.1678904	32.34%
58	Stockton	California	322,120	2.83	2.00	2.32	2.49	3.22	9.47	4.38	10	16.71200725	33.42%
61	Riverside	California	317,261	3.09	2.00	2.17	1.80	3.76	9.59	4.31	10	16.71226428	33.42%
48	Bakersfield	California	407,615	3.87	2.00	3.35	1.61	2.52	9.07	4.37	10	16.78811513	33.58%



Additionally, it was seen that New York City - the most populous city in America - has a 51.25% chance of a shooting occurring, which was surprising due to the city's strict gun laws.

Overall, of the 100 cities tested, 53 cities had probabilities of mass shooting occurrence that were 50% or more.

In the 60-day time span from the end of the procedure, February 18th, 2023 to April 19th, 2023, 90 mass shootings occurred throughout the nation. Of these 90, 51 occurred in just the 100 most populated cities including major mass shootings such as those that occurred in Louisville and Nashville. Out of these 51 shootings, 36 were marked by the algorithm, prior to the incident, to have a probability of mass shooting occurrence higher than 50% to have a mass shooting occur. All 51 cities were marked by the algorithm to have a probability of occurrence higher than 40%. From these current observations on accuracy, the results seem somewhat notable. Looking at the ROC-Curve comparing the predicted occurrence likelihood and whether a shooting occurred or not for the 2-month period, there is a 0.691 AUC value, suggesting that the algorithm isn't perfect at guessing though would be better than randomly guessing mass shooting occurrence. The longer timeframe of February 1st to August 1st provided an AUC value of 0.709 which is slightly higher than the 2 months's AUC. However, a longer timeframe along with data recollection would be necessary to confirm if the algorithm's results are statistically significant.

From this, it can be seen that the mathematical algorithm created for this project does indeed work and can be applied to predict mass shooting occurrences in a city with some accuracy. This means that a model to predict the likelihood of the occurrence of mass shootings is feasible though may require improvement.

Based on the algorithm's results, 6 out of the 10 cities at the highest risk of mass shootings are in the South, which was expected due to the South's loose gun laws. The other 4 cities at the most risk were in the Midwest and the Southwest. The city at the most risk is Atlanta, Georgia which was not surprising considering the history of gun violence in the city. These cities that were identified as being at higher risk can benefit from targeted policy interventions and it should be noted that the model is more so a tool for finding where preventative action is necessary rather than a tool to call out inevitabilities. On the other hand, the 10 cities with the least risk are all in the Pacific West, with 7 of these cities being in California, which was also expected due to the region's strict gun laws. The city at the least risk was Honolulu, Hawaii, which was also not surprising due to the state's isolation from the rest of the country.

Among the 8 factors, the factors that most commonly affect the cities with the highest probabilities of occurrence were their close proximity to previous incidents, high gun store densities, and weaker gun laws. These findings align with previous research showing that increased firearm availability is linked to higher rates of gun violence and that stricter gun laws strongly correlate with lower rates of gun violence. Surprisingly, however, most of these high-scoring cities had smaller gun ownership rates than the national average, though they still had higher rates than most other cities tested. Another important finding to consider was that many high-risk cities had a higher gun store density than their commercial area density, despite their commercial area density being higher than average. This means that these cities had more gun stores than they did malls or shopping centers, which is very concerning.

Among the 8 different factors, the most commonly apparent in the cities with the lowest probabilities were low gun ownership rates, lower income inequality ratios, low gun dealership densities, and stricter gun laws. Addressing these factors, especially through decreasing gun dealership densities and increasing gun law severity, can potentially help deter the risk of mass shootings and make a city safer.

These results show what factors need to be considered to make cities safer for the future and can help policymakers prioritize high-risk cities for interventions such as stricter zoning laws for gun dealerships, community-based violence prevention programs, or stricter gun purchase and carry policies. If more local gun policies can be implemented, this could lead to a significant decrease in the probability of mass shooting occurrences. However, it should be noted that the implementation of such policies will require the collaboration of policymakers, researchers, and the communities where the policies are being implemented in order for these policies to be effective in increasing safety. The results also show that spontaneous events like mass shootings can indeed be predicted in a somewhat accurate manner which is important to note for all fields of research in the future.

However, this research has several limitations which must be considered. One such limitation is that the area-density-based factors of commercial area density and gun dealership density needed to be counted and calculated by hand, which could have led to inconsistency or error in the collection and calculation of data. However, this error would likely not be large enough to skew results due to these factors only being a portion of the factors observed. This limitation may be addressed in the future through the use of automated tools such as OpenStreetMap APIs. It is also important to note the potential limitations caused by the assumption of feature independence among the risk factors considered within the algorithm. This assumption may have led to potential error leading to some factors actually being overconsidered or underconsidered. Another limitation was the long process involved in data collection. Each city's data took around 10-20 minutes to collect for a total of around 25 hours to complete the process of data collection for all 100 cities. If the process had been shorter, more cities could have been considered in the research process. Additionally, the fact that risk factors can change over time needs to be considered when predicting mass shooting likelihood as these changes can lead to outdated predictions if not correctly kept up to date.

In the future, this project could be expanded upon by using AI to collect all data through a standardized procedure, not only improving accuracy but making it possible to include much more than just 100 cities in data collection while keeping data up to date. This would allow for the expansion of the model for use in mid-sized cities and rural areas to better generalize its findings. Other risk factors besides the eight considered here could also be factored into the procedure, such as age demographics or even law enforcement metrics, potentially allowing for more accurate predictions of the probability of occurrence. It may also help to conduct case studies on cities that have already successfully reduced violence through policy interventions which can then be used to determine other possible risk-adding or risk-deterring factors. In addition, further analysis of the economic and social impacts of mass shootings in these cities could be done in order to help strengthen potential policy arguments. To better test the model's predictive accuracy in the future, multi-year data sets could be tested by using data from different periods in the set. Future research could also make use of a similar mathematical algorithm, in order to see which types of gun control may be the most effective in reducing mass shooting occurrences.

Overall, this algorithm can be used to determine the probability of a mass shooting occurrence in cities throughout the nation, which can then be used to determine if precautions need to be taken for a city. It can also help determine what specific precautions may be needed by using the scores from each individual risk factor. Using this information could help prevent these mass shootings from occurring and potentially save thousands of lives per year.

Appendix

Calculated Mass Shooting Probability Values for All Tested Cities

Population Rank	City	State	Probability of Occurrence
1	New York	New York	51.25%
2	Los Angeles	California	41.68%
3	Chicago	Illinois	45.14%
4	Houston	Texas	66.12%
5	Phoenix	Arizona	56.86%
6	Philadelphia	Pennsylvania	63.18%
7	San Antonio	Texas	56.71%
8	San Diego	California	30.95%
9	Dallas	Texas	64.95%
10	San Jose	California	40.83%
11	Austin	Texas	58.59%
12	Jacksonville	Florida	36.95%
13	Fort Worth	Texas	59.37%

14	Columbus	Ohio	54.17%
15	Indianapolis	Indiana	56.37%
16	Charlotte	North Carolina	57.31%
17	San Francisco	California	45.08%
18	Seattle	Washington	31.77%
19	Denver	Colorado	51.94%
20	Oklahoma City	Oklahoma	55.37%
21	Nashville	Tennessee	55.41%
22	El Paso	Texas	52.82%
23	Washington	District of Columbia	44.86%
24	Boston	Massachusetts	42.37%
25	Las Vegas	Nevada	58.34%
26	Portland	Oregon	36.56%
27	Detroit	Michigan	59.31%
28	Louisville	Kentucky	53.87%
29	Memphis	Tennessee	53.55%

30	Baltimore	Maryland	42.23%
31	Milwauke e	Wisconsin	60.24%
32	Albuquer que	New Mexico	49.70%
33	Fresno	California	41.27%
34	Tucson	Arizona	56.40%
35	Sacramen to	California	43.21%
36	Mesa	Arizona	62.14%
37	Kansas City	Missouri	52.84%
38	Atlanta	Georgia	72.48%
39	Omaha	Nebraska	42.59%
40	Colorado Springs	Colorado	51.48%
41	Raleigh	North Carolina	51.84%
42	Virginia Beach	Virginia	43.90%
43	Long Beach	California	43.06%
44	Miami	Florida	47.87%

45	Oakland	California	38.55%
46	Minneapolis	Minnesota	42.85%
47	Tulsa	Oklahoma	62.55%
48	Bakersfield	California	33.58%
49	Wichita	Kansas	46.95%
50	Arlington	Texas	61.29%
51	Aurora	Colorado	45.00%
52	Tampa	Florida	52.07%
53	New Orleans	Louisiana	58.77%
54	Cleveland	Ohio	72.04%
55	Anaheim	California	40.56%
56	Honolulu	Hawaii	12.76%
57	Henderson	Nevada	46.72%
58	Stockton	California	33.42%
59	Lexington	Kentucky	54.66%
60	Corpus Christi	Texas	55.73%
61	Riverside	California	33.42%

62	Santa Ana	California	36.69%
63	Orlando	Florida	66.21%
64	Irvine	California	35.16%
65	Cincinnati	Ohio	64.56%
66	Newark	New Jersey	39.67%
67	Saint Paul	Minnesota	41.97%
68	Pittsburgh	Pennsylvania	54.81%
69	Greensboro	North Carolina	48.32%
70	St. Louis	Missouri	59.95%
71	Lincoln	Nebraska	42.42%
72	Plano	Texas	58.30%
73	Anchorage	Alaska	48.97%
74	Durham	North Carolina	47.82%
75	Jersey City	New Jersey	44.01%
76	Chandler	Arizona	51.01%

77	Chula Vista	California	26.61%
78	Buffalo	New York	53.69%
79	North Las Vegas	Nevada	44.78%
80	Gilbert	Arizona	56.79%
81	Madison	Wisconsin	51.58%
82	Reno	Nevada	49.39%
83	Toledo	Ohio	53.98%
84	Fort Wayne	Indiana	52.45%
85	Lubbock	Texas	50.71%
86	St. Petersbur g	Florida	57.31%
87	Laredo	Texas	47.84%
88	Irving	Texas	54.08%
89	Chesapea ke	Virginia	36.06%
90	Winston–Salem	North Carolina	53.33%
91	Glendale	Arizona	58.76%

92	Scottsdale	Arizona	57.08%
93	Garland	Texas	58.40%
94	Boise	Idaho	52.26%
95	Norfolk	Virginia	44.44%
96	Spokane	Washington	26.80%
97	Fremont	California	29.41%
98	Richmond	Virginia	56.53%
99	Santa Clarita	California	39.42%
100	San Bernardino	California	32.34%

References

Bast, S., & DeSimone, V. (2019). Understanding the Factors. In *Youth Violence Prevention in the United States: Examining International Terrorists, Domestic Terrorists, School Shooters, and Gang Members* (pp. 11–27). Center for Strategic and International Studies (CSIS). http://www.jstor.org/stable/resrep22584.9

Blair, J. P., & Schwieit, K. W. (2013, November 30). A study of active shooter incidents in the United States between 2000 and 2013. US Department of Justice. Retrieved October 28, 2022, from https://eric.ed.gov/?id=ED594362

Booty, M., O'Dwyer, J., Webster, D., McCourt, A., & Crifasi, C. (2019). Describing a "mass shooting": The role of databases in understanding burden. Injury Epidemiology, 6(1). https://doi.org/10.1186/s40621-019-0226-7

Braga, A. A. (2001). More Gun Laws or More Gun Law Enforcement? Journal of Policy Analysis and Management, 20(3), 545–549. http://www.jstor.org/stable/3326136

Duggan, M., Hjalmarsson, R., & Jacob, B. A. (2011). THE SHORT-TERM AND LOCALIZED EFFECT OF GUN SHOWS: EVIDENCE FROM CALIFORNIA AND TEXAS. The Review of Economics and Statistics, 93(3), 786–799. http://www.jstor.org/stable/23016077

Duwe, G., Sanders, N. E., Rocque, M., & Fox, J. A. (2022). Forecasting the Severity of Mass Public Shootings in the United States. Journal of Quantitative Criminology, 38(2), 385–403. https://doi.org/10.1007/s10940-021-09499-5

Fox, C., & Harding, D. J. (2005). School Shootings as Organizational Deviance. Sociology of Education, 78(1), 69–93. http://www.jstor.org/stable/4148911

Fox, J. A., & Levin, J. (2021). Mass murder in america: Trends, characteristics, explanations, and policy response. Homicide Studies, 26(1), 27–46. https://doi.org/10.1177/10887679211043803

Gun Violence Archive. (2023). Gun violence archive. Gun Violence Archive. Retrieved from https://www.gunviolencearchive.org/reports/mass-shooting

Kwon, R., & Cabrera, J. F. (2019). Socioeconomic factors and mass shootings in the United States. Critical Public Health, 29(2), 138–145. https://doi.org/10.1080/09581596.2017.1383599

Lin, P.-I., Fei, L., Barzman, D., & Hossain, M. (2018). What have we learned from the time trend of mass shootings in the U.S.? PLoS ONE, 13(10), 1–13. https://doi.org/10.1371/journal.pone.0204722

McCarthy, M. (2014). Mass shootings on rise in US, says FBI report. BMJ: British Medical Journal, 349. https://www.jstor.org/stable/26517288

Philpott-Jones, S. (2018). policy and politics: Mass Shootings, Mental Illness, and Gun Control. *The Hastings Center Report*, 48(2), 7–9. http://www.jstor.org/stable/26628085

Reeping, P. M., Cerdá, M., Kalesan, B., Wiebe, D. J., Galea, S., & Branas, C. C. (2019). State gun laws, gun ownership, and mass shootings in the US: Cross Sectional Time Series. BMJ, l542. https://doi.org/10.1136/bmj.l542

Santilli, A., O'Connor Duffany, K., Carroll-Scott, A., Thomas, J., Greene, A., Arora, A., Agnoli, A., Gan, G., & Ickovics, J. (2017). Bridging the Response to Mass Shootings and Urban Violence: Exposure to Violence in New Haven, Connecticut. American journal of public health, 107(3), 374–379. https://doi.org/10.2105/AJPH.2016.303613

Sen-Crowe, B., Autrey, C., Newsome, K., Mckenney, M., & Elkbuli, A. (2021). Mass shootings and their proximity to a public or private school: Protecting the health and livelihood of our children. The American Surgeon, 88(11), 2695–2702. https://doi.org/10.1177/00031348211063557

Smart, R., & Schell, T. L. (2021, April 15). Mass shootings in the United States. rand.org. Retrieved from https://www.rand.org/research/gun-policy/analysis/essays/mass-shootings.html

Sommeiller, E., & Price, M. (2018, July 19). The New Gilded Age: Income inequality in the U.S. by state, Metropolitan Area, and County. Economic Policy Institute. Retrieved from https://www.epi.org/publication/the-new-gilded-age-income-inequality-in-the-u-s-by-state-metropolitan-area-and-county/#epi-toc-14

US Census Bureau. (2021, April 20). City and town population totals: 2020-2021. Census.gov. Retrieved from https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-cities-and-towns.html

Zakopoulos, I., Varshney, K., Macy, J. T., & McIntire, R. K. (2022). A Descriptive Analysis of Mass Shootings in the United States From 2010 to 2020: The Relationship Between Firearm Dealership Density and Proximity to Mass Shooting Sites and a Comparison With McDonald's and Starbucks Retailers. Cureus, 14(9), e29302. https://www.cureus.com/articles/103927-a-descriptive-analysis-of-mass-shootings-in-the-united-states-from-2010-to-2020-the-relationship-between-firearm-dealership-density-and-proximity-to-mass-shooting-sites-and-a-comparison-with-mcdonalds-and-starbucks-retailers#!/