GUN VIOLENCE & FIREARM REGULATIONS: AN INVESTIGATION OF CORRELATIONS BETWEEN WEAPON-RELATED INCIDENTS & CURRENT LEGISLATIVE POLICIES THROUGH NATURAL LANGUAGE PROCESSING AND MACHINE-LEARNING

RONALD FENG

Rye Country Day School, Rye, New York, USA.

KEYWORDS

Gun Control, Mass Shootings, School Shootings, Correlation, Firearm Laws, Legislation.

ABSTRACT

In recent years, gun violence in the United States has emerged as a significant public health concern with profound societal impact. Nevertheless, firearms regulations remain highly controversial and divisive. In most cases, federal laws are limited in scope and each state therefore implements its own gun policies and regulations. This study explores current data regarding gun violence and state level firearms laws to examine their relationship. To accomplish this task, sophisticated statistical and machine learning models were used to determine the most effective firearms laws to deter gun violence. This research further underscores the fact that firearms regulations are not widely supported in many regions of the country. The NLP (Natural Language Process) analysis on the gun violence data revealed public and crowded spaces are frequent targets for gun crimes. These studies further found out certain firearms laws are more associated with gun incidents. Finally, this investigative study applied machine-learning modeling to identify the 6 most important firearms laws associated with gun violence. Our research paves the way for policymakers to evaluate the effectiveness of current firearm laws and provide data-driven solutions to resolve the current crisis.

I.   INTRODUCTION

According to the National Institute of Health, more than 30,000 Americans were killed and over 60,000 were injured annually over the past 40 years on account of firearms. Furthermore, gun crimes in the US are consistently higher than nearly every other nation. Perhaps the most alarming, however, is the fact that there are many brutal school and mass shootings each year resulting in large quantities of fatalities and injuries. Between 2000 and 2019, for example, there were 250 such incidents. Moreover, in just a little more than 3 years since 2020, there were already 117 incidents. The upward trend continues to rapidly escalate, adversely impacting all society and especially students. In fact, three million children are directly exposed to gun violence each year. In the 2012 Sandy Hook Elementary School shooting, for example, 26 people were killed including 20 first-grade children aged six and seven. In Parkland, Florida in 2018, a 19-year-old gunman opened fire armed with a semi-automatic rifle, killing 17 and injuring another 17 persons. In Uvalde, Texas in 2022, an 18-year-old former student entered an elementary school and killed 19 students and 2 teachers while injuring 17 others. Incidents like these are becoming increasingly commonplace as gun violence rates continue to rise.

Firearms assaults have an immense societal impact and frequently cause lasting physical and psychological damage [5]. Exposure to gun violence can cause stress, anxiety, anger, depression,

suicidal behavior, and many other mental health disorders. Research has also demonstrated that when children and teens are exposed to violence and crime, they are increasingly likely to become addicted to drugs and alcohol as well as exhibit greater rates of violent behavior and criminal activity later in life [6]. While gun violence has a devastating impact on society, it also adversely affects cities and neighborhoods as well as businesses and real estate. Assaults with firearms contribute to urban blight, depreciating housing prices, impeding business development, and increasing security and maintenance costs. Overall, the financial and social cost of gun violence is monumental. According to the American Psychiatric Association, 87% of Americans believe that an act of violence with guns is a public health threat.

Rationale

Rising incidents of gun violence have aroused significant public debate as American society grapples with ways to deter such activities. As such, gun control remains a highly contentious issue, dividing entire communities. Proponents of gun control promote stricter firearms laws to increase public safety, while opponents of gun restriction regulations argue that stricter firearms laws are unconstitutional, violating their Second Amendment rights and usurping their constitutional liberties. Proponents and opponents are deeply entrenched in their positions and the United States Congress has been at loggerheads for years, unable to take decisive action. Without comprehensive, uniform federal legislation, gun regulations vary widely from state to state both in terms of statutes. At the current moment, 133 different firearms laws exist on the books nationwide. While there are a profuse number of gun regulations, the impact of these laws has not been fully studied. In particular, although some firearms laws might be more effective for deterring gun violence, others may have little or no impact whatsoever. Altogether, more scientific research comparing and contrasting gun violence and the efficacy of specific firearms laws are needed.

As an innovative technology, machine learning (ML) has been widely applied to many scientific research fields for classification and prediction. One advantage of ML is its efficiency to process large data sets and to clearly identify and clarify critical trends, features, and components. This study combines time series analysis, statistical analysis, natural language process (NLP), and machine learning (ML) to explore the relationship between gun violence data and state-level firearms law acceptance data. Two ML models were built to identify the most effective firearms laws that deter gun violence. Using dual ML models cancels differences between each algorithm, thereby ensuring significant reliability of the results.

Objectives
Research Goals/Hypothesis
Research Goals

Explore gun violence data and firearm law data to identify trends and correlations between specific firearms laws and gun incidents both by state and by year.
Examine and evaluate the impact of each firearm law on gun violence.
Build machine learning models to determine the most effective firearm laws that deter gun violence.

Hypothesis

Certain laws are more effective than other regulations in deterring gun violence. State incidents of firearms assaults will vary, depending on the types of legislation enacted.

II.   LITERATURE REVIEW

A few prior studies have been conducted on determining the relationship between firearm laws and gun violence. Kwon et al applied multiple linear regressions to statistically and empirically evaluate the effectiveness of gun control laws that have been adopted by states and municipalities. The study categorized the states according to strictness of firearm laws and studied various correlations between gun control measures and violent deaths. The research concluded that gun control laws have a negligible impact on reducing firearm-related homicides.

Another study performed time-series analyses from 1980 to 2019 to investigate the impact of specific firearms laws including child access prevention, minimum age requirements for gun purchases, and mandatory gun safety training laws on school firearm incidents. This investigation concluded that these laws demonstrated an inconsistent relationship with gun violence at schools.

Kalesan et al used Poisson regression with robust variances to derive incidence rate ratios for determining the impact of different firearm laws on all gun-related fatalities including cases of both homicides and suicides across the entire United States. The study's findings projected the potential reduction of firearms mortality by enacting three specific laws most strongly associated with incidents involving death. All three of these research studies either focus on specific firearm laws or particular gun crimes.

Finally, Schell et al. [10] studied 3 firearm law classes – child access prevention, right-to-carry, and stand your ground, from 1970 to 2016, and applied Bayesian methods to evaluate their association with firearms-related deaths. This study discovered a high probability of an association between the implementation of child access prevention laws and the reduction of firearm-related death.

III.   METHODOLOGY
Data Collection & Preprocessing

All data in this research was collected from reliable and authoritative sources. This research utilized three datasets: gun violence data, firearm law data, and statewide population. Each dataset was a time series. These three datasets were combined into a comprehensive dataset capable of training the machine learning model and testing its results. New features were also created to feed into analysis and models.
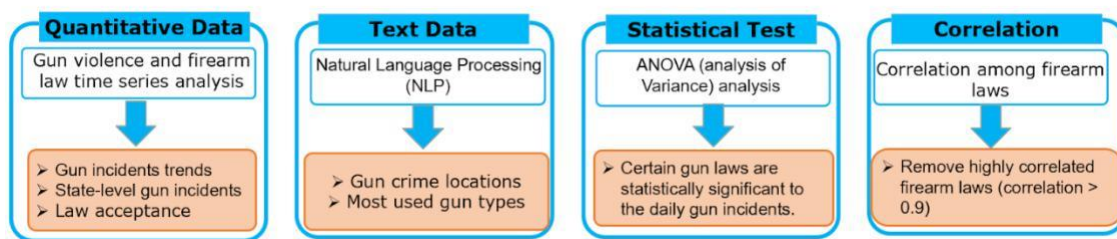
Data Analysis

Figure 1. Data Analysis Process

Figure 1 illustrates the procedural steps followed in this study to analyze the three independent datasets. After data cleaning, the merged information was carefully scrutinized to determine trends in gun incidents. Additionally, this research examined gun incidents on a state-by-state basis. An analysis of the firearm law dataset was performed to ascertain insight into nationwide acceptance of firearm laws. In addition to quantitative and numerical data, the gun violence dataset also encompassed highly valuable qualitative, textual information. To unveil concealed patterns or insights embedded within the textual data, advanced Natural Language Processing (NLP) techniques were employed.

An analysis of variance (ANOVA) test was also conducted to examine the relationship between 133 different gun laws and the daily count of gun incidents in each state. This test aimed to determine if there were statistically significant differences in gun incidents from the various implementations of firearm laws. In this context, the independent variable was represented by each specific gun law, while the dependent variable consisted of the daily count of gun incidents in each state.

Machine-Learning Models

After the ANOVA test identified certain firearm laws as statistically significant factors related to gun violence, machine learning models were constructed by the team to identify the most influential firearm laws. To ensure model accuracy, highly correlated firearm laws were removed prior to model development. In this study, we constructed and compared two machine learning models, namely XGBoost and Random Forest, to determine the most influential firearm laws. The inclusion of both models allowed us to account for potential variations arising from different learning algorithms.

IV.   RESULTS AND DISCUSSION
Gun Violence Statistics

Figure 2 shows the number of gun incidents and victims by year across an 8-year timespan. The left graph displays gun violence statistics from 2014-2021. Although gun incidents do not show

an increasing linear trend, the total number s reaches an all-time high in 2020. Data from 2013 and 2022 were removed from this graph because data in those 2 years are incomplete. The graph on the right depicts the number of gun crime victims over the same years. It illustrates a recent sharp increase of victims.
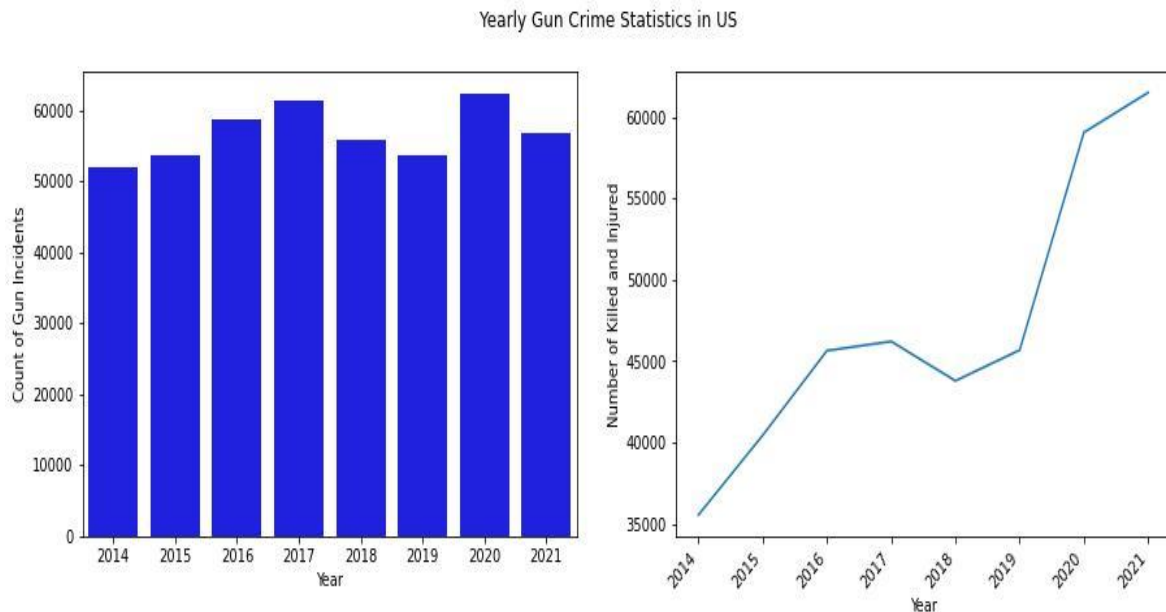

Figure 2. Gun Incidents and Victims by Year

Firearm Laws Acceptance by State

The left graph in Figure 3 displays the sorted count plot of gun violence incidents in each state from 2013 to 2022. On initial observation, it appears that populous states such as Illinois, California, Texas, and Florida have by far the most gun violence incidents while states with smaller populations, such as South Dakota, Wyoming, and Vermont, have a significantly lower number of incidents. In contrast, the right graph in Figure 3 shows normalized gun incidents per 1 million inhabitants. After normalization, the findings change. The District of Columbia emerges as the most prone to gun violence per capita followed by states such as Louisiana, Delaware, Illinois, and Alaska. In comparison, California, Texas, and Florida have statistically lower daily gun crime incidents in the normalized chart.

Figure 4 shows state implementation of various gun regulations over the years. More than half of states have implemented between 15 to 40 firearm laws. Only a small number of states such as California, New Jersey, New York, Connecticut, Hawaii, and Illinois have enacted more than 60 laws. This figure also shows that while gun policies have become stricter over the years in some states, several states from 1991-2020 have eliminated several of their gun regulations including Alabama, Alaska, Arkansas, Georgia, and South Carolina.

Figure 5 displays the implementation of each firearm law in the US in 2021. Only a few laws such as cc background (background check on concealed carry), cc renew background (background check on renewal of concealed carry), and felony (prohibition for people with felony) are implemented in most states. Of the total number of 133 firearms laws on the books across the nation, less than 20 states have implemented at least 120 of them. The data analysis of the firearm laws reveals that support for stricter gun control is generally very low in the United States. In terms of public policy, it appears that identifying the most effective firearms laws is more efficient and practical than implementing many firearm laws.
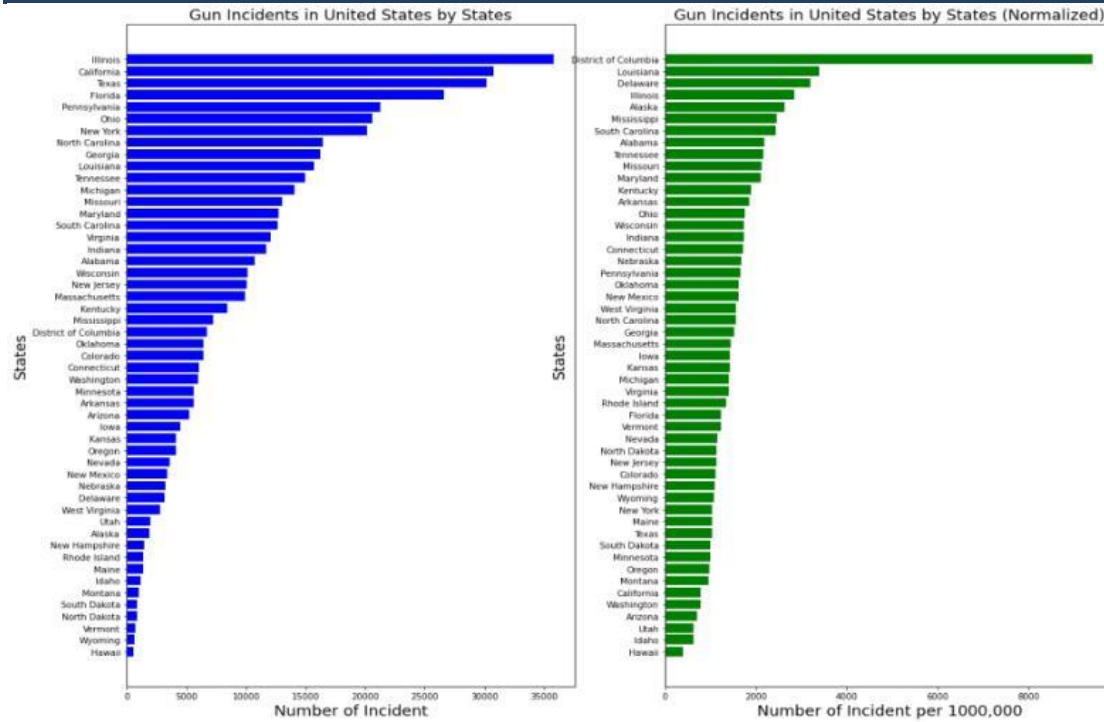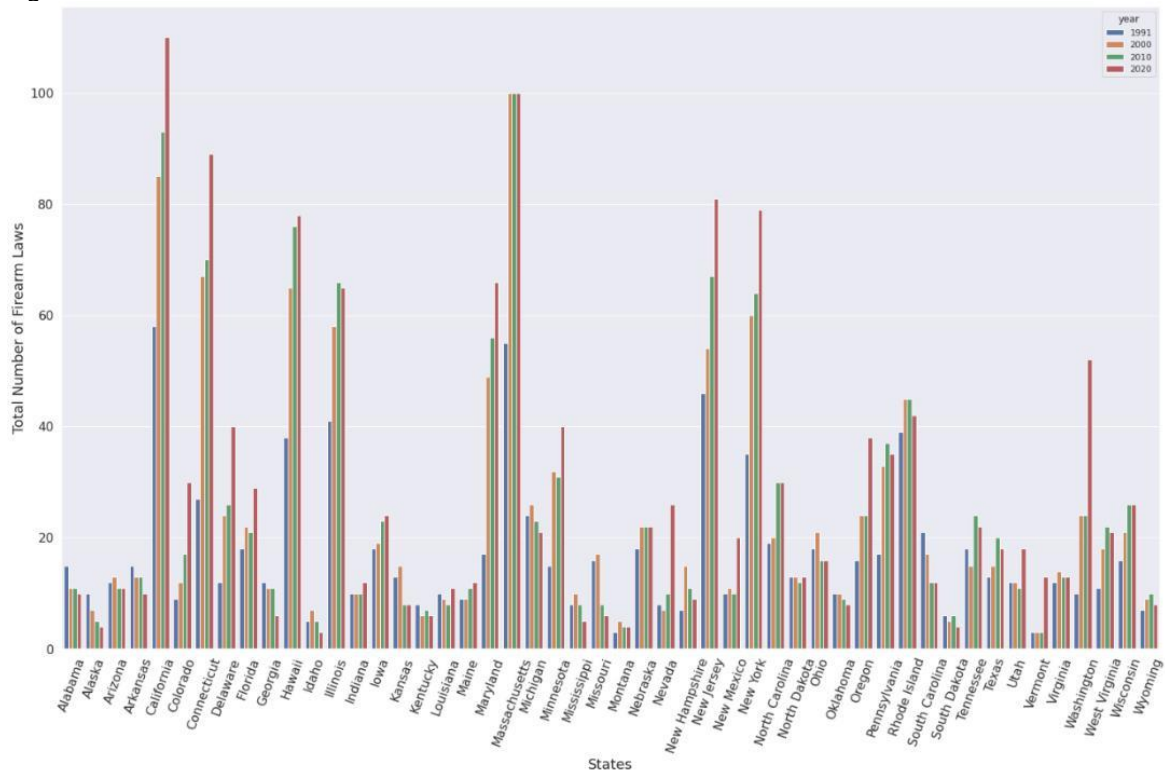
Figure 3. Gun Incidents Per State

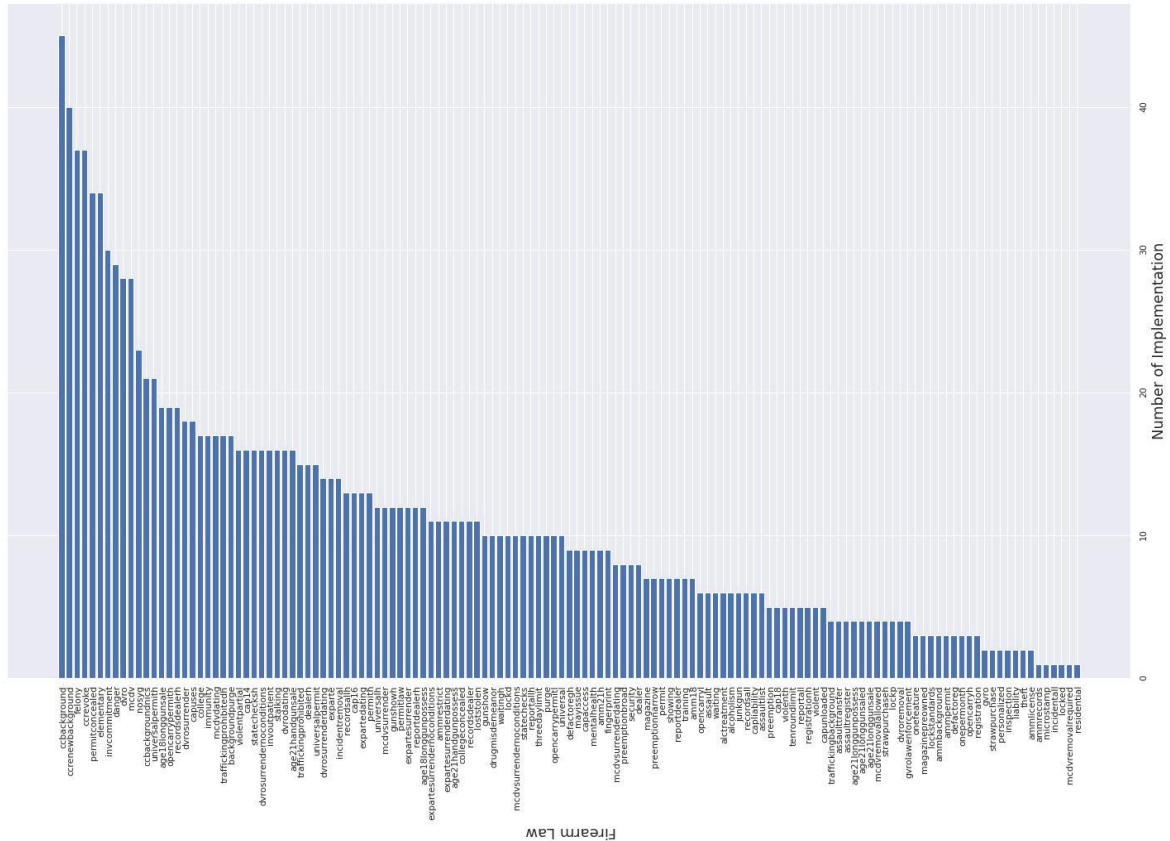Figure 4. Firearms Law Implementation by State

Figure 5. Individual Firearm Law Implementation in 2021

Natural Language Processing (NLP) Analysis

The NLP data analysis resulted in some interesting findings. Figure 6 shows the Word Cloud for gun crime locations. The larger the word, the more often gun crime happens at that particular place.
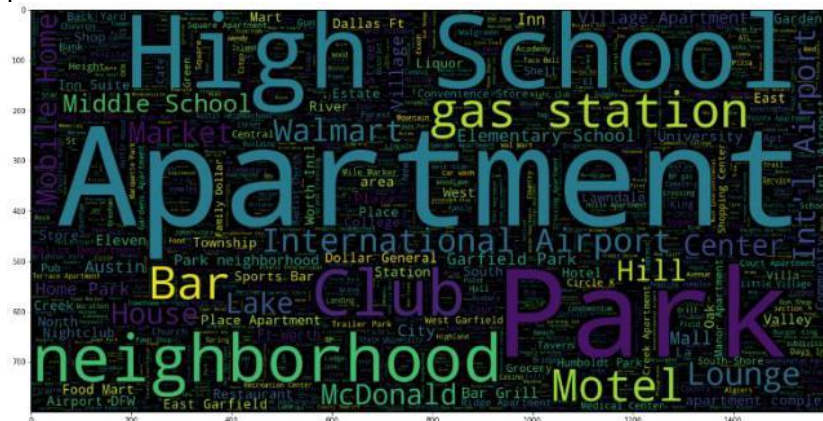

Figure 6. Word Cloud of Gun Incident Locations

Figure 7 displays the number of gun incidents in terms of compound nouns or two-word combinations. The locations where gun violence occurs most frequently include apartments, high schools, parks, clubs, neighborhoods, and airports. An analysis indicates that with the exception of apartments, most gun crimes take place in public and crowded areas. In terms of the most frequent gun crime locations, according to Figure 7, high schools, middle schools, and elementary schools are ranked 1st, 6th, and 7th, respectively. This fact alone raises immediate concern about school safety and mental health among teenagers among other considerations including tighter security precautions.
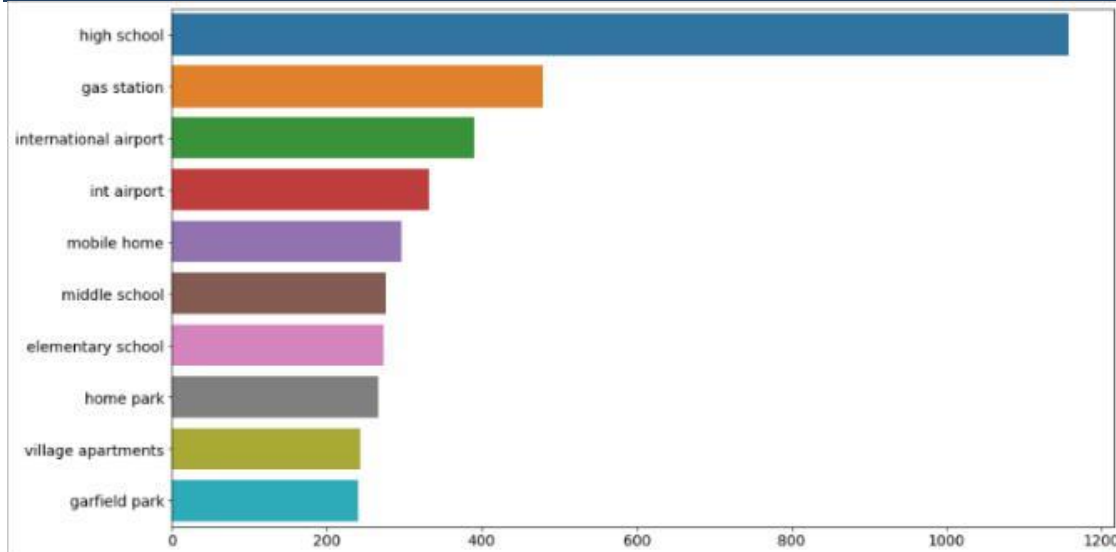
Figure 7. Number of Gun Incidents in Two-Words Location

Statistical Analysis

Figure 8 illustrates a sample of the ANOVA test result. The laws – age 18 long gun sale, alcoholism, alc treatment, amm background, have p value less than 0.05, which means they have a statistically significant relationship with gun incidents. The df value, degree of freedom, for the groups is 1 because there are only two values, 0 and 1, for each law. In this case, the ANOVA test result is the same as the t-test. The ANOVA test was chosen because this statistical technique was also used to analyze other features with three categories in this research. Our ANOVA test shows 98 out of 133 gun laws are statistically significant in relationship to daily gun incidents. Based on the ANOVA test, further machine-learning techniques can be performed to precisely determine the importance of specific gun laws on firearm incidents.

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                  df        sum_sq        mean_sq          F      PR(>F)
age18longgunsale  1.0   6.169466e+06  6.169466e+06  8.384215  0.004079
Residual        284.0   2.089794e+08  7.358430e+05       NaN       NaN
                  df        sum_sq        mean_sq           F     PR(>F)
alcoholism        1.0   9.440857e+06  9.440857e+06  13.034024  0.000361
Residual        284.0   2.057080e+08  7.243240e+05        NaN       NaN
                  df        sum_sq        mean_sq           F     PR(>F)
alctreatment      1.0   7.547595e+06  7.547595e+06  10.325162  0.001463
Residual        284.0   2.076013e+08  7.309905e+05        NaN       NaN
                  df        sum_sq        mean_sq          F      PR(>F)
ammbackground     1.0   9.049491e+06  9.049491e+06  12.46998  0.000482
Residual        284.0   2.060994e+08  7.257021e+05       NaN       NaN
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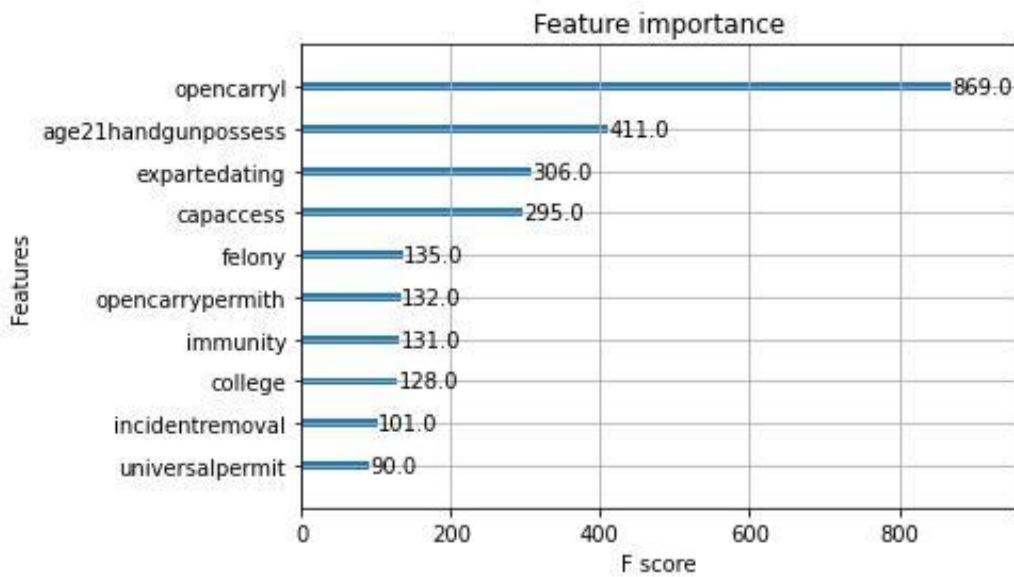Figure 8. ANOVA Results

Machine-Learning Results
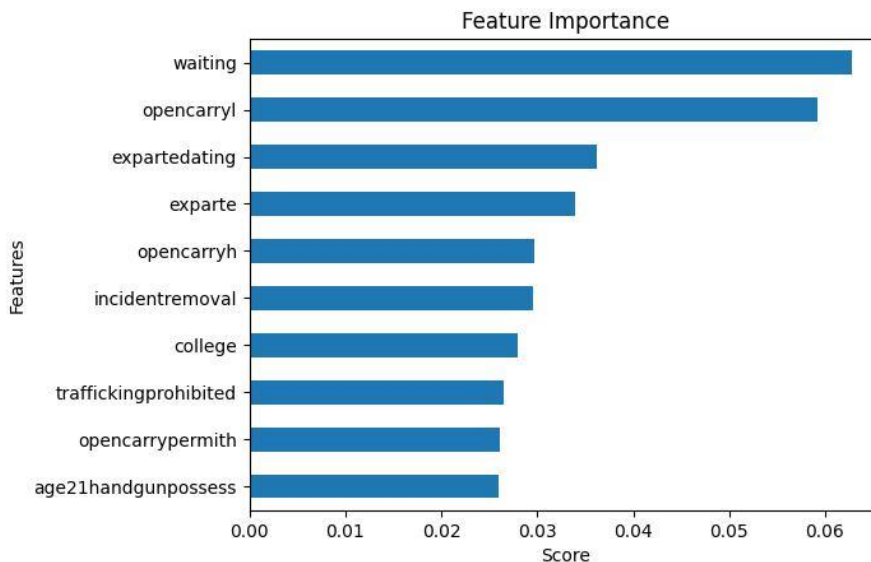
Figure 9. XGBoost Top 10 Important Features

Figure 10. Random Forest Top 10 Important Features

Figure 9 and Figure 10 plot the top 10 most important gun law features generated by XGBoost and Random respectively. The higher the score, the greater the association with daily gun incidents. Although the underlying algorithms are different, both models generate similar results concerning the most important features of effective gun legislation. The same 6 firearm features show up in the top 10 list in both models including a) open carry(no open carry of long guns is allowed in public places), b) age21handgunpossess (purchase of handguns from licensed dealers and private sellers restricted to age 21 and older), c) expartedating (the prohibition on firearm possession if the petitioner is a dating partner of the DVRO subject), d) open carry permit (no open carry of handguns is allowed in public places without permit), e) college (no gun carrying allowed on college campuses except for concealed weapon permittees), and f) incident removal (state law requires law enforcement to remove firearms from the scene of a domestic violence incident). The model results of this research align with the previous data analysis findings which reveal that gun violence incidents occur more often in public places, such as high schools, airports, parks, etc. Especially important in reducing or preventing gun violence are restrictions on carrying guns in public places, the age at which guns may be purchased, and gun ownership requirements designed to keep weapons out of the hands of dangerous persons. Among these most important features, none of these has been

implemented by more than 20 states. Opencarryl and age21longgunpossess are only adopted by 6 and 11 states, respectively.

The findings of this research have important implications and ramifications for society. Perhaps, for example, the horrific2022 shooting at Robb Elementary School in Uvalde, Texas, the third deadliest school shooting in the US, could have been avoided altogether if the proper legislation had been enacted. On this occasion, an 18-year-old former student killed 21 people including nineteen students and two teachers. The lone gunman legally purchased two AR rifles within one week after reaching his 18th birthday and committed the massacre just 7 days later on May 24, 2022., In Texas, not only can people purchase firearms at age 18 but they are also permitted to carry their weapons in public without a license. With opencarryl and age21longgunpossess being the two most important violence-prevention features discovered in this study, it appears that these innocent lives could potentially have been saved if these just these two laws alone had been enacted by the state legislature.

V.   CONCLUSIONS AND RECOMMENDATION

Gun violence is a serious public safety and health concern in the United States. This problematic situation highlights the necessity of conducting further research to study the impact of firearm laws on gun violence. This paper applied advanced machine learning techniques to identify the most important firearm laws associated with daily gun incidents. The study performed data analysis on gun violence data and firearm law data. The results demonstrate that there has been a substantial upwardrise in gun incidents, injuries, and fatalities in recent years. Nevertheless, public acceptance of firearms restrictions is very low in the US. The NLP analysis conducted in this study indicates that public and crowded places tend to be the primary target of gun crimes. Furthermore, this study also showed a strong correlation between specific firearm laws and incidents of gun violence. By building two machine learning models, Random Forest and XGBoost, this study identified the most important features associated with daily gun incidents. Both models identified the same 6 firearm laws among the top 10 most important laws associated with daily gun incidents. None of the aforementioned laws has been implemented in more than 20 states. The two most important regulations, opencarryl and age21longgunpossess, have only been adopted by 6 and 4 states respectively. Altogether, the significant findings culminating from this investigation should provide lawmakers with invaluable guidance as to which firearm laws should be implemented as part of an effective and comprehensive firearms legislative policy.

Future directions of study elicited by the findings of this research should apply a multi-dimensional approach to gun violence. While many influences are frequently cited as contributing factors to the current crisis including mental health and racially divergent attitudes concerning firearms, media is also highly influential in shaping societal values and perspectives. In this connection, the next proposed study will apply a variety of statistical analyses to determine how media representation of gun violence affects marginalized communities. This future study will also extend its focus to encompass mass shootings and especially school massacres. Understanding how to prevent these tragic events is crucial for protecting citizens across America.

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