# MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE GWALIOR

(A Govt. Aided UGC Autonomous Institute Affiliated to RGPV, Bhopal)

***NAAC Accredited with A++ Grade***

**Project Report**

**on**

# Crime Analysis State-Level Insights via K-Means Clustering


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# CERTIFICATE

This is certified that **Avinash Gupta** (0901AM211019), **Mayank Uchariya** (0901AM211030) has submitted the project report titled **Crime Analysis State Level Insights via K-means clustering** under the mentorship of **Dr. Vibha Tiwari**, in partial fulfilment of the requirement for the award of degree of Bachelor of Technology in **Artificial Intelligence and Machine Learning** from Madhav Institute of Technology and Science, Gwalior.

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# DECLARATION

I hereby declare that the work being presented in this project report, for the partial fulfilment of requirement for the award of the degree of Bachelor of Technology in **Artificial Intelligence and Machine Learning** at Madhav Institute of Technology & Science, Gwalior is an authenticated and original record of my work under the mentorship of **Dr. Vibha Tiwari, Assistant Professor**, Centre for Artificial Intelligence

I declare that I have not submitted the matter embodied in this report for the award of any degree or diploma anywhere else.

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# ABSTRACT

This project conducts a comprehensive analysis of crime rates across Indian states and Union Territories. Leveraging K-means clustering, it meticulously dissects the data to reveal nuanced regional patterns. By examining multi-year datasets, the study uncovers intricate temporal trends and scrutinizes correlations between crime rates and diverse demographic factors. Highlighting the crucial significance of state-level analyses, the findings serve as a cornerstone for informed policymaking and proactive law enforcement strategies. This research, focusing on regional disparities, aims to craft targeted interventions that address specific societal challenges prevalent across different regions, the study's paramount goal is to contribute substantively to the creation of safer, more cohesive communities on a national scale. By shedding light on these complex dynamics, it seeks to empower decision-makers with actionable insights for a more secure societal landscape.



***Keyword: Crime Rates, K-Means Clustering, Regional Patterns***

# सार:

यह प्रोजेक्ट भारतीय राज्यों और केंद्र शासित प्रदेशों में अपराध दरों का एक व्यापक विश्लेषण करता है। इसमें K-मीन्स क्लस्टरिंग का प्रयोग करके डेटा को विस्तृत रूप से जांचा जाता है ताकि क्षेत्रीय पैटर्न्स पता लगाया जा सके। मल्टी-वर्षीय डेटासेट की जाँच के माध्यम से, यह अध्ययन जटिल समयांतर रुझानों को प्रकट करता है और अपराध दरों और विविध जनसांख्यिकीय कारकों के बीच संबंधों की जांच करता है। राज्य स्तरीय विश्लेषण के महत्त्व को महसूस कराते हुए, इस अध्ययन के परिणाम सूचनात्मक नीति निर्माण और सक्रिय कानूनी रणनीतियों के लिए मूलभूत होते हैं। यह शोध, क्षेत्रीय असमानताओं पर ध्यान केंद्रित करते हुए, निर्दिष्ट सामाजिक चुनौतियों के लिए टारगेटेड हस्तक्षेपों का निर्माण करने का प्रयास करता है। अंत में, इस प्रोजेक्ट का उद्देश्य राष्ट्रीय स्तर पर एक सुरक्षित और समर्पित समुदाय के निर्माण में महत्त्वपूर्ण योगदान करना है। इन जटिल गतिविधियों को प्रकाशित करके, यह निर्णय लेने वालों को एक सुरक्षित समाजी मंज़र के लिए क्रियाशील जानकारी प्रदान करने का उद्देश्य रखता है।

*कीवर्ड - अपराध दरें, के-मीन्स क्लस्टरिंग, क्षेत्रीय पैटर्न्स*

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# Chapter 1: PROJECT OVERVIEW

## 1.1 Introduction

This report delineates a paradigm shift from conventional crime prediction methodologies to the adoption of data-driven approaches, notably emphasizing the pivotal role of technology in enhancing crime data analysis. The evolution towards methodologies like data mining is underscored, elucidating how these technologies unearth intricate patterns within crime data. It explores the nuances of crime parameters and their inherent limitations in handling voluminous datasets, emphasizing the need for more advanced methods.

Furthermore, the report delves into the profound impact of crime on a nation's development, encompassing offenses ranging from theft to severe crimes like assault and murder, prevalent across diverse regions. It underscores the pressing need for efficient tools capable of swiftly analysing historical crime data and predicting evolving patterns. Advocating the fusion of data mining and machine learning for proactive crime prevention strategies, particular attention is given to the significant role of clustering techniques, notably the K-Means method, in discerning patterns and curbing crime rates.

Additionally, insights into open-source platforms such as 'R,' 'WEKA,' and Java-based tools are explored for their efficacy in extracting and leveraging data crucial for law enforcement purposes. The study exclusively utilizes the extensive National Crime Records Bureau (NCRB) dataset spanning from 2001 to 2021, focusing on State/UT wise crime data in India based on the Indian Penal Code (IPC), offering a comprehensive analysis for informed decision-making and policy formulation.

## 1.2 Objectives and Scope

This comprehensive report endeavours to explore the evolutionary journey from traditional crime prediction methodologies to the contemporary landscape of data-driven approaches, with a focal point on the pivotal role of technology, notably data mining, in revolutionizing crime data analysis. It seeks not only to evaluate the constraints entrenched within traditional approaches for managing and interpreting extensive datasets but also to advocate for the implementation of more sophisticated analytical tools capable of navigating these limitations.

Delving deeper into the societal ramifications of criminal activities, this study aims to shed light on the multifaceted impacts of various offenses, ranging from minor misdemeanours to severe felonies such as assault and homicide, witnessed across diverse geographical landscapes. Moreover, it endeavours to underscore the urgency for comprehensive, advanced analytical methods to forecast and deter crime patterns effectively. The integration of cutting-edge techniques such as data mining, machine learning, and the intricate nuances of clustering, notably the K-Means method, stands central to this discussion, showcasing their potential in discerning and mitigating criminal activities.

Furthermore, the report aims to offer an insightful evaluation of open-source platforms like 'R,' 'WEKA,' and Java-based tools, elucidating their functionalities and roles in extracting and harnessing valuable data for law enforcement purposes. This extensive analysis draws upon the rich repository of the National Crime Records Bureau (NCRB) dataset spanning from 2001 to 2021. The focus on State/UT wise crime data in India, meticulously categorized based on the Indian Penal Code (IPC), aims to provide nuanced insights essential for fostering informed decision-making and policy formulation strategies in the realm of crime prevention and societal well-being.

## 1.3 Project Features

The project encompasses several crucial features designed to analyze and understand crime dynamics at the state/UT level. It involves the utilization of multi-year crime data sourced from reliable government repositories like the National Crime Records Bureau (NCRB). The dataset incorporates key attributes such as crime counts, population statistics, crime rates, and categorical crime types across different regions and years. Leveraging machine learning techniques, particularly K-means clustering, the project aims to categorize states/UTs based on their crime rates, providing insights into distinct patterns and regional disparities.

## 1.4 Feasibility

The project is highly feasible due to reliable crime datasets from government sources like the National Crime Records Bureau. Leveraging machine learning, especially K-means clustering, on this data appears viable for its ability to handle large volumes and identify patterns. Focusing on state/UT-level analysis offers a manageable scope, providing significant insights into regional crime dynamics. Extracting correlations between crime rates and demographics supports targeted interventions and policy decisions, making this project promising for understanding and addressing crime patterns.

## 1.5 System Requirements

All crime analysis experiments and data processing procedures were executed utilizing a laptop equipped with a 2.5 GHz Dual Core Intel® Core i5 processor, 8 GB of memory, and a 512 GB SSD hard drive. Despite these moderate hardware specifications, the model demonstrated robust capabilities in processing and analysing extensive crime datasets effectively. Furthermore, for handling larger volumes of data and conducting more intricate analyses, experiments were also conducted using a Google Collab, significantly augmenting computational capacity for in-depth crime pattern recognition and analysis.

# CHAPTER 2: LITERATURE REVIEW

Traditional approaches in crime analysis predominantly relied on statistical techniques such as descriptive statistics and regression models to understand crime patterns. However, the evolution of machine learning, particularly clustering methods like K-means, has revolutionized the field. Past research demonstrates the power of clustering algorithms in uncovering nuanced patterns within crime data, especially at the state or regional level. These studies showcase how K-means clustering effectively partitions data into clusters, delineating areas with varying crime rates and distinct socio-economic profiles.

For instance, research focusing on Indian states/UTs has utilized clustering methods to categorize regions into sensitive, moderate, and peaceful areas based on crime rates. This spatial segmentation offers critical insights for policymakers and law enforcement agencies, enabling them to prioritize interventions and resource allocation according to the severity of crime prevalence in different regions. Clustering techniques have unveiled intricate correlations between crime rates and socio-economic factors. Studies have highlighted how factors like population density, unemployment rates, education levels, and income disparities significantly impact crime dynamics. By leveraging clustering methodologies, researchers have identified these influential variables, emphasizing the need to address socio-economic disparities as a means to curb crime effectively.

Despite the successes, challenges persist. Determining the optimal number of clusters and ensuring their validity remains a subject of ongoing research. Studies acknowledge the need for more robust validation methods and sophisticated algorithms to enhance the reliability and interpretability of clustering results.

Looking forward, the research trajectory aims to refine clustering models by integrating advanced algorithms, incorporating additional dimensions such as temporal data, and exploring the impact of urbanization and social policies on crime patterns. Future studies aspire to create more dynamic and adaptable models capable of predicting crime trends, enabling law enforcement and policymakers to proactively address emerging challenges.

Past research unequivocally highlights the transformative impact of clustering methods in deciphering crime patterns, elucidating nuanced spatial categorizations, and unveiling intricate correlations between various socio-economic factors and crime prevalence. These methods have been instrumental in informing targeted interventions, aiding law enforcement strategies, and guiding policy formulations aimed at curbing crime. The iterative advancements in clustering techniques, evident from historical studies, signify a promising trajectory towards increasingly sophisticated crime analysis frameworks.

# CHAPTER 3: PRELIMINARY DESIGN

In this we are analysing crime at the state level, focusing on the utilization of K-means clustering techniques within a multi-dimensional framework. The study incorporates diverse socio-economic and crime-related datasets sourced from reliable government repositories, ensuring data consistency and reliability. The initial phase involves data preprocessing, encompassing data cleaning, normalization, and feature engineering to prepare the dataset for analysis. Following this, exploratory data analysis (EDA) techniques, such as descriptive statistics, visualization methods, and correlation analyses, will be employed to elucidate the distributions, trends, and potential relationships within the datasets. Subsequently, K-means clustering, a widely adopted unsupervised learning algorithm, will be applied to categorize states/UTs based on crime rates, aiming to unveil distinct spatial patterns and identify sensitive, moderate, and peaceful areas. Evaluation metrics, including silhouette scores and cluster validation techniques, will ascertain the optimal clustering configuration. The preliminary design emphasizes a structured and iterative approach, integrating advanced data analytics methodologies to unravel intricate crime dynamics prevalent across different geographical regions.

## 3.1 Unsupervised learning

Unsupervised learning, notably the K-means clustering technique, plays a pivotal role in our project's crime analysis at the state level. This machine learning paradigm enables the algorithm to autonomously identify patterns within crime data without predefined categories. K-means clustering partitions states/UTs into clusters based on crime rate similarities, facilitating the delineation of sensitive, moderate, and peaceful areas. By revealing hidden structures and correlations, unsupervised learning empowers our analysis to unveil distinct crime patterns and spatial dynamics across regions, guiding targeted interventions and policy decisions aimed at enhancing community safety and law enforcement strategies.

## 3.2 Clustering

Clustering, particularly K-means, constitutes a fundamental methodology in our project's crime analysis at the state level. The working principle involves an iterative process aimed at partitioning states/UTs into distinct groups based on crime rate similarities. K-means operates by initially assigning a predetermined number of centroids randomly to the dataset, representing the cluster centers. Subsequently, each data point, symbolizing a state/UT, is assigned to the nearest centroid based on a defined distance metric, often Euclidean distance, forming initial clusters. The algorithm iteratively adjusts centroid positions to minimize the sum of squared distances between data points and their respective centroids, refining cluster boundaries. This iterative reassignment and centroid adjustment continue until convergence, signifying stable clusters. The resultant clusters represent spatially distinct categories—sensitive, moderate, and peaceful areas—enabling a nuanced understanding of crime dynamics across geographical regions. The scientific essence of K-means lies in its iterative optimization process, delineating cohesive clusters based on crime rate similarities, providing a structured framework for spatial categorization essential in our crime analysis.

### 3.2.1 K-Means

K-means clustering is a method used to partition a dataset into K clusters by minimizing the sum of squared distances within each cluster. The process begins by randomly selecting K data points as initial cluster centroids. In the assignment step, each data point is evaluated for its distance to each centroid using a distance metric like Euclidean distance. Data points are then assigned to the nearest centroid, forming initial clusters. The centroids are updated by recalculating their positions based on the mean of the data points assigned to each cluster. This iterative process of assignment and centroid update continues until convergence, where centroids no longer change significantly. The objective is to minimize the sum of squared distances between data points and their respective centroids. This iterative optimization aims to create clusters where data points within each cluster are more similar to each other while being dissimilar to data points in other clusters, thus delineating distinct clusters based on similarities in the dataset's feature space

$$J = \sum_{\underset{\text{cluster}}{j=1}}^{\overset{\text{No. of clusters}}{k}} \sum_{\underset{\text{data point}}{i=1}}^{\overset{\text{No. of data points}}{n}} \underbrace{\left\| \overset{\text{data point belonging to cluster } j}{x_i^{(j)}} - \overset{\text{centroid}}{\mu_j} \right\|^2}_{\text{Euclidian distance}}$$

### 3.2.2 Silhouette Score

The Silhouette Score is a metric used to assess the quality of clusters formed by a clustering algorithm, such as K-means. It measures how well-separated the clusters are and how similar each data point is to its assigned cluster compared to other clusters.

The score is calculated for each data point and ranges from -1 to +1. A score close to +1 indicates that the data point is well within its own cluster and far from neighbouring clusters, signifying a strong and appropriate clustering. A score near 0 implies that the data point is close to the decision boundary between clusters. Scores below 0 suggest that data points might have been assigned to the wrong clusters.

$$s(i) = \frac{b(i) - a(i)}{\max\left(a(i), b(i)\right)}$$

# CHAPTER 4: FINAL ANALYSIS AND DESIGN

## 4.1 Data collection and preprocessing

The study relies on an extensive dataset consolidating crime counts, population statistics, and relevant variables across Indian states and Union Territories (UTs). This dataset is meticulously sourced from reliable government repositories, ensuring a high degree of consistency and reliability. Prior to analysis, a rigorous preprocessing phase is undertaken, encompassing data cleaning, normalization, and handling missing values. This meticulous preprocessing methodology aims to ensure the integrity and robustness of subsequent analytical procedures.

| | state_ut | district | year | rape | kidnapping_and_abduction |
|---|---|---|---|---|---|
| 0 | ANDHRA PRADESH | GUNTAKAL RLY. | 2001 | 0 | 0 |
| 1 | ANDHRA PRADESH | SECUNDERABAD RLY. | 2001 | 0 | 0 |
| 2 | ANDHRA PRADESH | VIJAYAWADA RLY. | 2001 | 1 | 0 |
| 3 | ARUNACHAL PRADESH | KAMENG WEST | 2001 | 0 | 2 |
| 4 | ARUNACHAL PRADESH | TAWANG | 2001 | 1 | 0 |
| 5 | ASSAM | C.I.D. | 2001 | 0 | 0 |
| 6 | ASSAM | G.R.P. | 2001 | 1 | 0 |
| 7 | ASSAM | R.P.O. | 2001 | 3 | 0 |
| 8 | BIHAR | ARWAL | 2001 | 0 | 0 |
| 9 | BIHAR | JAMALPUR RLY. | 2001 | 1 | 0 |
| 10 | BIHAR | KATIHAR RLY. | 2001 | 0 | 1 |
| 11 | CHHATTISGARH | BIZAPUR | 2001 | 4 | 0 |
| 12 | CHHATTISGARH | GRP RAIPUR | 2001 | 0 | 0 |
| 13 | CHHATTISGARH | KAWARDHA | 2001 | 35 | 0 |
| 14 | GUJARAT | W.RLY | 2001 | 1 | 0 |
| 15 | HARYANA | GRP | 2001 | 0 | 2 |

Figure 1

| | Category | State/UT | Year | Crime Count | Population (in lakhs) | Crime Rate |
|---|---|---|---|---|---|---|
| **0** | State | Andhra Pradesh | 2001.0 | 130089.0 | 757.28 | 171.784545 |
| **1** | State | Arunachal Pradesh | 2001.0 | 2342.0 | 10.91 | 214.665445 |
| **2** | State | Assam | 2001.0 | 36877.0 | 266.38 | 138.437570 |
| **3** | State | Bihar | 2001.0 | 88432.0 | 828.79 | 106.700129 |
| **4** | State | Chhattisgarh | 2001.0 | 38460.0 | 207.96 | 184.939411 |
| **5** | State | Goa | 2001.0 | 2341.0 | 13.44 | 174.181548 |
| **6** | State | Gujarat | 2001.0 | 103419.0 | 505.97 | 204.397494 |
| **7** | State | Haryana | 2001.0 | 38759.0 | 210.83 | 183.840061 |
| **8** | State | Himachal Pradesh | 2001.0 | 11499.0 | 60.77 | 189.221655 |
| **9** | State | Jammu & Kashmir | 2001.0 | 19505.0 | 100.70 | 193.694141 |

Figure 2

## 4.2 Exploratory Data Analysis

The Exploratory Data Analysis (EDA) for our crime-related dataset involves a structured approach to comprehend, clean, and explore the dataset's characteristics. Beginning with data collection from trusted sources like the National Crime Records Bureau (NCRB) encompassing Indian states/UTs, the initial step involves understanding the dataset's structure, including the number of records, columns, and their respective data types. Cleaning and preprocessing address missing values, outliers, and inconsistencies to ensure data integrity. Descriptive statistics unveil numerical attributes' central tendencies and variability, while categorical attributes are scrutinized through frequency distributions and unique values.

## 4.3 Assigning categories

The categorization process involves assigning distinct categories to states/UTs based on their respective crime rates. Utilizing specific thresholds or criteria, each region is classified into categories such as "Peaceful," "Moderate," or others, depending on their crime rate metrics. This categorization aids in discerning varying levels of crime prevalence across geographical areas, facilitating a nuanced understanding of crime dynamics. By establishing these categories, the analysis aims to identify patterns, correlations, and potential influencing factors unique to each category, providing valuable insights for targeted interventions and policy formulations specific to different levels of crime prevalence.

| | Category | State/UT | Year | Crime Count | Population (in lakhs) | Crime Rate | Crime Category |
|---|---|---|---|---|---|---|---|
| 0 | State | Andhra Pradesh | 2001.0 | 130089.0 | 757.28 | 171.784545 | Peaceful |
| 1 | State | Arunachal Pradesh | 2001.0 | 2342.0 | 10.91 | 214.665445 | Moderate |
| 2 | State | Assam | 2001.0 | 36877.0 | 266.38 | 138.437570 | Peaceful |
| 3 | State | Bihar | 2001.0 | 88432.0 | 828.79 | 106.700129 | Peaceful |
| 4 | State | Chhattisgarh | 2001.0 | 38460.0 | 207.96 | 184.939411 | Peaceful |
| 5 | State | Goa | 2001.0 | 2341.0 | 13.44 | 174.181548 | Peaceful |

Figure 3

## 4.4 Making and Visualisation of clusters

clustering on the 'Crime Rate' data, aiming to categorize it into three distinct clusters. Initially, the 'Crime Rate' column is extracted and stored in a variable named 'X.' The variable 'n_clusters' is set to 3, indicating the desired number of clusters for the K-means algorithm. The KMeans function is then initialized with three clusters and executed on the 'Crime Rate' data using the fit_predict method. This assigns cluster labels to each

'Crime Rate' entry based on their similarity, subsequently creating a new column labelled 'Cluster_CrimeRate' in the dataset. Each entry in this column signifies the assigned cluster for the corresponding 'Crime Rate,' enabling the segregation of data points into three distinct clusters based on their crime rate patterns.

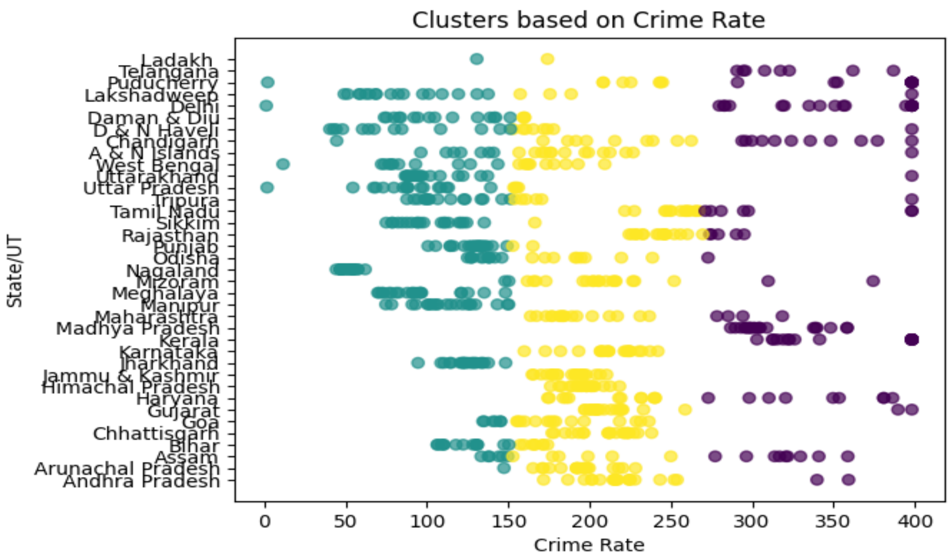


Figure 4

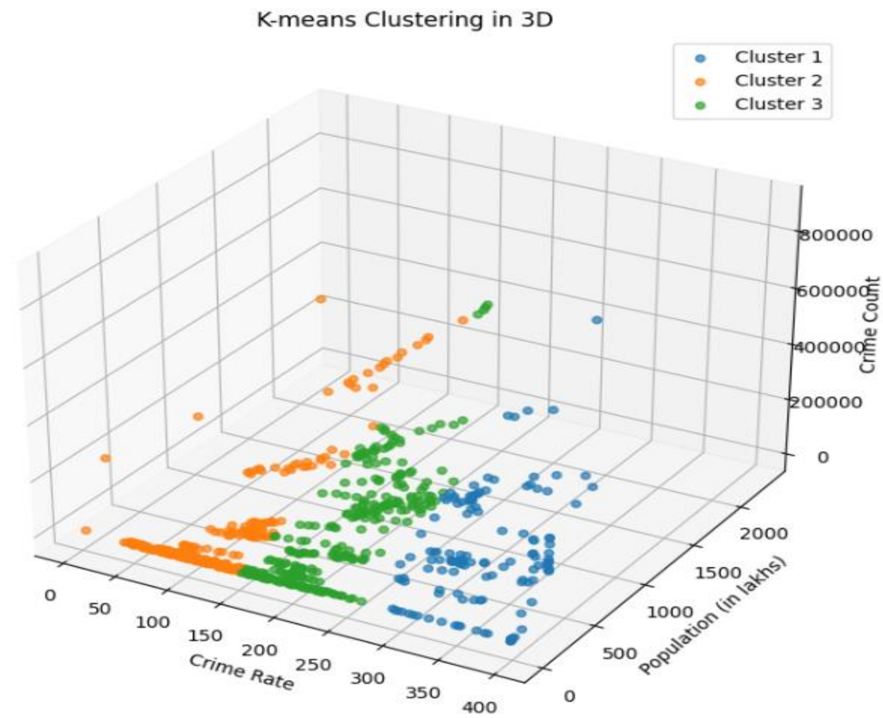


Figure 5

Figure 4 and Figure 5 offer insights into the distinctiveness among clusters concerning crime rates, population sizes, and crime counts. These visual representations contribute to a spatial understanding of diverse neighbourhood profiles and potential hotspots [8]. Specifically, cluster 1 signifies sensitive areas, cluster 2 denotes peaceful regions, and cluster 3 represents moderate areas. This characterization aids in delineating different neighbourhood profiles, facilitating targeted interventions based on the severity of crime prevalent in each cluster.


Figure 6

Figure 6, detailed in [9], displays the distribution of states/UTs across K-means clusters. Each bar represents state/UT counts within specific clusters, offering insights into their grouping and distribution.

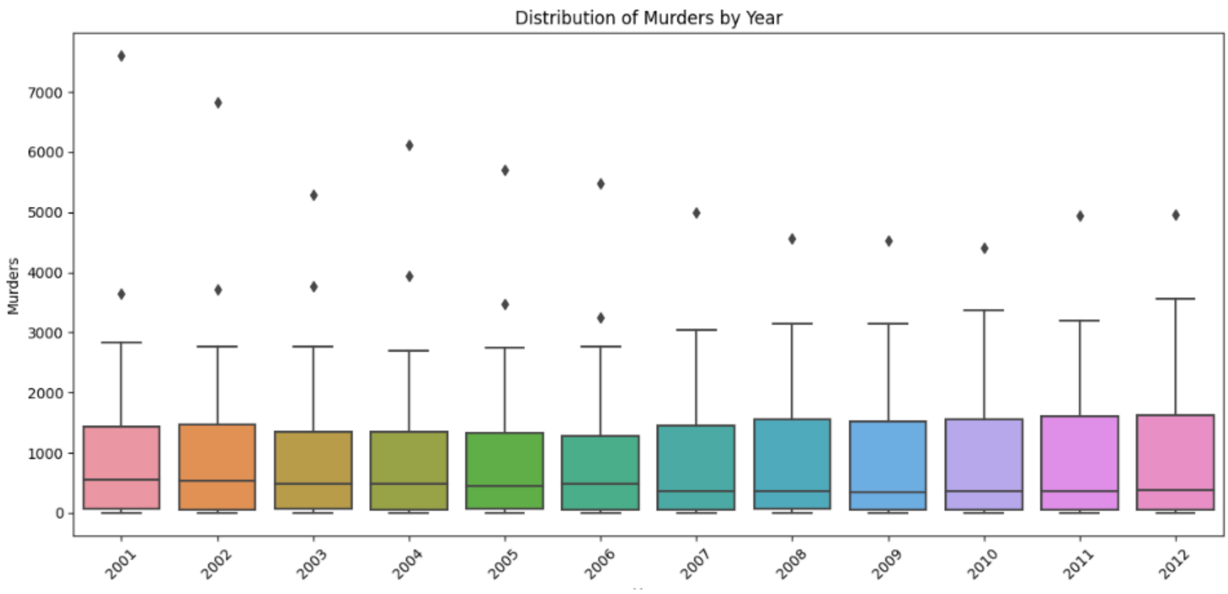


Figure 7

The above Figure 7 is a boxplot using Matplotlib and Seaborn, visualizing the distribution of murders across different years. The plot showcases variations in murder counts per year, with the x-axis representing the years and the y-axis displaying the number of murders. The plot's structure provides a clear insight into how murders are distributed throughout the specified years.

The Silhouette Score [10] of 0.60 aligns with the clustering evaluation scale of -1 to +1. This score suggests well-separated clusters with distinct boundaries and strong cohesion within each cluster, closer to the upper end of the scale (closer to 1). This indicates clearly defined clusters in the analysed data [11].

## 4.5 Conclusion

The analysis of sensitive areas uncovered significant correlations between socio-economic factors and crime prevalence [12]. Densely populated regions exhibited higher crime rates, suggesting the influence of population density. Socio-economic disparities, including limited access to education and employment, emerged as key influencers of crime. Targeted interventions are crucial for effective crime reduction. Implementing community-based policing initiatives [13] and investing in socio-economic development programs could address root causes and enhance security measures. Addressing the multi-faceted nature of crime in sensitive areas requires a collaborative, multi-dimensional approach [14] involving law enforcement, policymakers, social services, and local communities. Sustainable strategies should focus on holistic community development alongside enforcement efforts.

## 4.6 Future Scope

In perspective of ML models for crime analysis involves refining predictive algorithms to capture intricate relationships between socio-economic factors and crime prevalence. Advanced ML techniques like ensemble methods and deep learning architectures could enhance predictive accuracy, while integrating anomaly detection could enable early identification of emerging sensitive areas. Incorporating geospatial analysis and real-time data streams into models could offer a more granular understanding of crime dynamics, albeit ensuring ethical considerations remain integral to their deployment in law enforcement contexts.

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