

# Clustering of Indian States Based on Crime Incidences and Predicting Crimes Therein

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**Abstract** - To be pro-active in crime regulation, it is crucial to monitor and analyse crime incidences. Socio-economic and police data from 36 Indian states and union territories are considered for the period 2014-2018 to observe incidences of different types of crime. Certain crime incidences have shown an alarming rate of increase over this period, such as crime against women and children (13% increase), crime against senior citizens (30% increase), violent crimes (29% increase) and dowry related crimes (31% increase). Different states show different trends and intensities on different crime types making analysis of crime incidences more complex. Our study aims to cluster states on several crime parameters and predict specific crime incidences like murder, rape, dowry deaths, cheating, etc. Hierarchical clustering using agglomerative method is used to group states based on features related to crime. Multiple regression with feature selection technique is applied to identify key predictors of crime, which includes number of schools, number of jails, total and female police strength, number of police stations, police budget and police vehicles. Separate regression models are built for different types of crime, with R-squared ranging from 0.60 to 0.76. While total police strength is a key deterrent for murder cases, female police strength is a key deterrent for dowry deaths, number of schools and police vehicles are key deterrents for rape cases. Setting up a robust education system, improving police infrastructure and strengthening trained and mobile police force will curb specific crimes like murder, rape, dowry deaths etc., thereby making India safer and more business friendly.

**Keywords**— *crime analysis, crime in Indian states, crime prediction, hierarchical clustering, key predictors of crime, multiple linear regression, police data, socio-economic variables*

## I. INTRODUCTION

It is always better to prevent crimes rather than to punish the perpetrators of crime.

In India, the Criminal Procedure Code categorises crimes under two heads: cognizable and non-cognizable. In the former, police are responsible to take quick action based on a complaint received or on receipt of credible information. Cognizable crimes are either covered under the category of Indian Penal Code (IPC) or come under the purview of Special and Local Laws (SLL). Non-cognizable crimes, on the other hand, are supposed to be handled, pursued, and managed in the Court by the affected parties directly.

Several studies on global crime have given a low ranking to India based on actual data on crime surveys conducted. Certain crime incidences have shown an alarming rate of increase over the 5-year period (2014-2018) such as crime against women and children (13% increase), crime against senior citizens (30% increase), violent crimes (29% increase), kidnapping and abduction (41% increase), thefts (43%) and forgery (51%).

According to the National Crime Records Bureau (NCRB) of India [8], a governmental agency responsible for collecting and analysing crime data, one woman is raped every 29 minutes in India; one kidnapping takes place every 23 minutes; one person is murdered every 19 minutes and one property crime takes place every 5 minutes.

India is a vast country with more than 1.3 billion population and has a police force of just 2.1 million. [6] Indian Constitution assigns the responsibility for maintaining law and order to the States and Union

Territories, and almost all routine policing, including apprehending criminals, is carried out by state police forces. Through quasi-experiments, criminologists and economists have come to a consensus that a stronger police force leads to less crime.[7] Data from the United Nations Office on Drugs and Crime (UNODC) shows that in 2013, India's ratio of 138 police personnel per hundred thousand population was the fifth lowest among the 71 countries for which the agency collated these figures.[10]

High crime rate adversely affects growth of a nation, especially in the case of developing countries like India. [2] Not only it affects the country's internal stability and development, but the image of the country is also tarnished, impacting foreign investments and tourism, among others.

#### A. Literature Review:

Crime prediction has been of interest for a considerable time.

In 2011, Yu et al. [5] collated a data set containing the aggregated counts of different types of crimes and related events. Their model classified burglaries across a grid dividing a city into checkerboard-like cells. Within each cell, data was aggregated into six categories of residential burglary. They used several data mining and classification techniques to perform analytics which could aid crime forecasting. To stabilize results, a voting method was adopted.

In 2018, Deepika KK & Smitha Vinod [3] focused the crime analysis of Indian States and Union Territories during the period 2001 to 2012. Crime was identified using k-means clustering and the results were enhanced using the Google map marker clustering (GMAPI). A region was considered critical if the total IPC crime was greater than the average crime rate in that region. The Random Forest algorithm gave an accuracy of 99.93 % while The Neural Networks algorithm gave an accuracy of 90.02%.

An article by David et al. [9] utilized various innovative methods including clustering, text processing, crime pattern analysis by spatial and geo location-based methods, communication-based and finally prisoner-based method to identify various suspicious behaviour.

Manna and Biswas [4] studied the relationship between socio-economic factors like Gross Domestic Product (GDP), Human Development Index (HDI), inflation rate and unemployment in India with crime during the period 1900 to 2015. Cointegration and causality relations among the socio-economic factors and crime rate were

investigated. The results show that there is a unidirectional causal relation within socio-economic variables like unemployment, GDP and HDI.

Manuel Saldaña [1], in 2020 presented a model for analysis of criminal events from online newspapers, identifying the areas with the highest crime rates through the detection and geographical mapping of critical points and the analysis of the nature of the criminal event.

Forradellas et al. [12] in a recent paper, proposed a crime prediction model according to communes of Buenos Aires. The crimes (reported in period 2016–2019) selected to test the model were: homicides, theft, injuries, and robberies. A model was created according to the city area based on the SEMMA (Sample, Explore, Modify, Model, and Assess) model and after data manipulation, standardization and cleaning; clustering was performed using k-means and subsequently a neural network was generated. The model helped to obtain future information, not only regarding possible crimes, but also in the decision-making process for the distribution of the budget allocated to the security department.

In a recent overview paper, Mudgal et al. [13] presented a summary of the different methods and techniques used to identify, analyse and predict crimes. They discussed how crime detection and prediction can be carried out using association mining rules, k-means clustering, decision tree, artificial neural networks and deep learning methods. Mudgal et al. have proposed a model that can work on real-time crime prediction by recognizing human actions.

In addition, there exist multiple studies (Rafael Di Tella and Ernesto Schargrodsky [14], Ming Jen Lin [15], Aaron Chalfin and Justin McCrary [16]) which explains how, quantum as well as spatial distribution of police force impacts crime. Other studies (Mamta Mittal et al. [17], Jean Dreze and Reetika Khera [18], Anupreet Kaur Mavi [19], Paulo Buonanno [20], Peter Kitchen [21]) investigate influence of socio-economic parameters on crime.

Crime analytics is now an important area of study. Good reading material on relevant topics are available (Rachel Boba [22] and Statistics Canada [23] publications).

In the study done by Deepika KK and Smitha Vinod, the clustering and prediction was done only with the crime variables without usage of socio-economic variables. The analysis by Manna and Biswas involved the socio-economic variables but did not use any police variables as predictors of crime. The current study deals with IPC crimes like murder, rape, kidnapping and abduction, and SLL crimes

under the Narcotics Act, Explosives Act, Dowry Act etc. for the 36 states and union territories of India over a 5-year period from 2014 to 2018. It has been observed that different states show different trends and intensities on different types of crime, thereby making analysis of crime incidences more complex.

The current study aims to cluster states on several crime variables and predict incidences of specific crimes. based on both police and socio-economic variables.

## II. METHODOLOGY

### A. Data

The current analysis utilizes crime related data, data on police force and socio-economic data for 5-year period 2014 to 2018.

1) *Crime data:* The crime related data is abstracted from the NCRB (National Crime Records Bureau) portal which is available as a part of their annual reports. There are six broad categories of crime related data– IPC (Indian Penal Code) crimes, SLL (Special and Local Law) crimes, crimes against women, violent crimes, crimes against children and crimes against senior citizens. Each of these has subcategories of crimes under various sections.

2) *Data on police:* This data is abstracted from the annual publications ‘Data on Police Organisation in India’ (DoPo) of BPRD (Bureau of Police Research & Development). Each of the publications is prepared based on data provided by states and union territories, Central Armed Police Forces and other police organisations.

3) *Socio-economic data:* This data is collected from various Indian Government websites.

Table 1 contains a list of all the variables considered under the three categories.

### B. Exploratory Data Analysis

Total IPC crimes in India have increased from 2.95 million in 2015 to 3.24 million in 2018. Total crime against women in India has increased from 0.33 million in 2015 to 0.39 million in 2018 (Figure 1). Kidnapping and abduction has increased from 78.4thousand in 2014 to 110.4 thousand in 2018. However, rape cases have come down from 36.9 thousand cases in 2014 to 33.9 thousand in 2018 (Figure 2). Dowry deaths show a drop from 8.5 thousand in 2014 to 7.3 thousand in 2018. However, several states show markedly different trend compared to India-overall. While crimes against women show an increasing trend at all India level, the same shows decreasing trend in states of Rajasthan and West Bengal.

Table 1. List of variables under study

Crime Data		Police Data	Socio-economic Data
<ul style="list-style-type: none"> <li>• Murder</li> <li>• Kidnapping and abduction</li> <li>• Theft</li> <li>• Robbery</li> <li>• Cheating</li> <li>• Liquor and narcotics crimes</li> </ul>	<ul style="list-style-type: none"> <li>• Rape</li> <li>• Dowry deaths</li> <li>• Trespassing and burglary</li> <li>• Outrage to modesty of woman</li> </ul>	<ul style="list-style-type: none"> <li>• Total police strength</li> <li>• Women police strength</li> <li>• Police zones</li> <li>• Police stations</li> <li>• Police budget</li> <li>• Police training budget</li> <li>• Vehicles per police stations</li> <li>• Personal computers</li> </ul>	<ul style="list-style-type: none"> <li>• Population</li> <li>• GDP growth rate</li> <li>• Inflation rate</li> <li>• Number of schools</li> <li>• Unemployment rate</li> <li>• Number of jails</li> </ul>

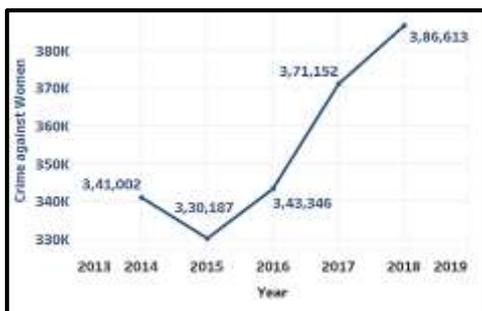


Figure 1. Increase in crimes against women (India)

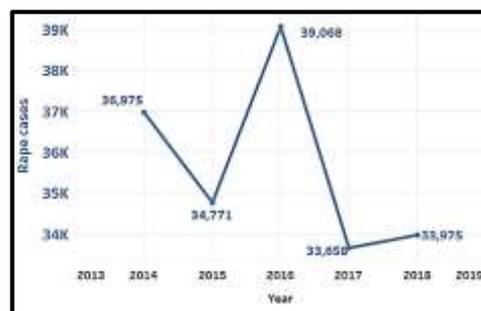


Figure 2. Rape incidences reported (India)

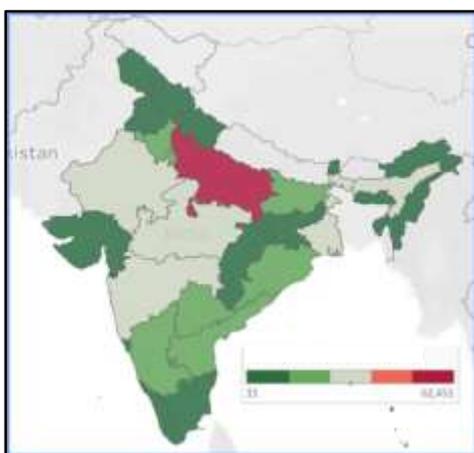


Figure 3. UP is the top state for crimes against women

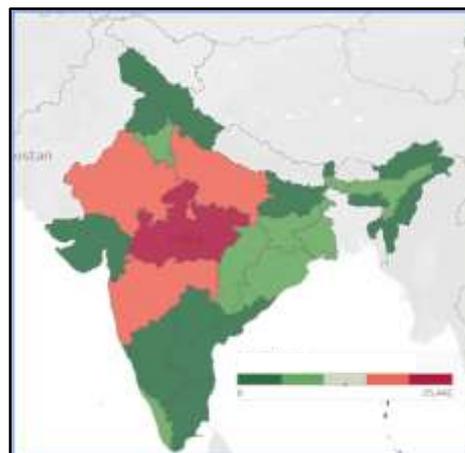


Figure 4. MP is the top state for rape cases

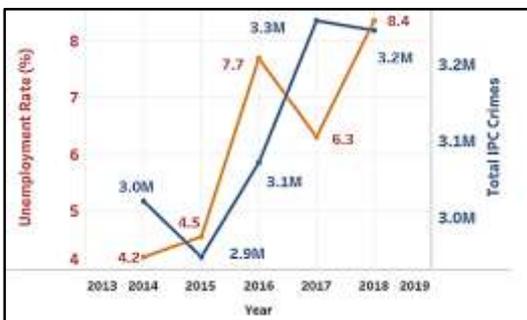


Figure 5. Unemployment shows a direct relationship with total IPC crimes (India)

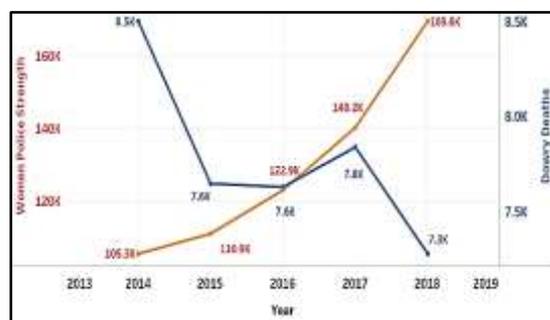


Figure 6. Women police strength shows an inverse relationship with dowry deaths (India)

States behave differently in different types of crimes. Uttar Pradesh tops the list for crimes against women (Figure 3) whereas Maharashtra tops the list for crimes against senior citizens. The number of reported rape cases is highest in the state of Madhya Pradesh (Figure 4). Gujarat records highest number of incidences of crimes related to liquor and narcotics. Note that Figures 3 and 4 are not normalized by population nor by total area of the state.

Figure 5 depicts a direct relationship of reported crimes with unemployment, whereas inflation rate and GDP show inverse relationship with reported crimes at all India level. On the other hand, whereas in both Karnataka and Gujarat inflation rate shows upward trend, crime against women is showing an increasing trend in Gujarat but a decreasing trend in Karnataka. Figure 6 shows the inverse relationship between women police strength and dowry deaths.

### C. Clustering

Since the Indian states show differential behaviour among themselves, clustering similar states together is the first step in understanding dependency of crime on the police and socio-economic variables.

Data for the year 2018 was considered for clustering purpose.

To avoid the problem of scaling, all variables are converted into ordinal scales based on their deciles (1 to 10: low to high). Hierarchical agglomerative clustering has been used with average linkage.

Two different partitions are made on the states and union territories.

1) Partition 1: Select IPC crimes, SLL crimes and crimes against women as shown below are used in this clustering exercise.

- *IPC Crimes* - Murder, kidnapping and abduction, theft, riots.

- *SLL Crimes* - Arms Act 1959, gambling act, liquor and narcotic drugs related acts.

- *Crimes against women* - Rape, assault on women with intent to outrage her modesty, insult to modesty of women, cruelty by husband or his relatives.

The resultant clusters are shown in Table 2.

2) Partition 2: Besides the fact that crime against women in India has grown by 13% during the period of 2014-2018, India ranks 133 out of 167 countries

Table 2. Partition 1

Clusters	States/Union territories
Cluster 1 [14 States]	Arunachal Pradesh, Goa, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, A&N Islands, Chandigarh, D&N Haveli, Daman & Diu, Lakshadweep and Puducherry
Cluster 2 [4 States]	Himachal Pradesh, Jammu & Kashmir, Punjab and Uttarakhand
Cluster 3 [18 States]	Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, West Bengal and Delhi

in Women Peace and Security Index for 2019-20 [11]. Thus, only crimes against women are considered for clustering. The resultant clusters are shown in Table 3.

Note that Cluster 1 is identical in both partitions.

#### D. Predictive modeling

The next objective is to identify key predictors for specific crimes in the identified clusters through multiple linear regression models.

#### Modeling Approach:

Since each cluster contains states and union territories of various sizes, all state-specific variables are normalized by state population. For each selected crime, correlations with the police and socio-economic variables are computed.

Using the police and socio-economic variables with high correlations, regression models are built using backward elimination procedure.

Based on the high R<sup>2</sup> values, models are shortlisted basis which key predictors of specific crimes are identified.

### III. RESULTS AND DISCUSSION

#### A. Clustering:

Cluster profiles based on Partitions 1 and 2 are described in Tables 4 and 5, respectively.

Table 3. Partition 2

Clusters	States/Union territories
Cluster 1 [14 States]	Arunachal Pradesh, Goa, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, A&N Islands, Chandigarh, D&N Haveli, Daman & Diu, Lakshadweep and Puducherry
Cluster 2 [9 States]	Bihar, Chhattisgarh, Gujarat, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Punjab, Tamil Nadu, Uttarakhand
Cluster 3 [13 States]	Andhra Pradesh, Assam, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Telangana, Uttar Pradesh, West Bengal, Delhi

Table 4. Cluster Profile – Partition 1 (Numbers denote averages for the variables for all states in the cluster)

Variables	Cluster 1	Cluster 2	Cluster 3
<b>Crime variables</b>			
IPC crimes (per lakh population)	40	35	67
SLL crimes (per lakh population)	29	65	86
Crimes against women (per lakh population)	9	14	18
<b>Police variables</b>			
Police strength in state (per lakh population)	581	327	133
Women police strength in state (per lakh population)	45	23	12
Female population per women police	1041	2018	4035
Police stations (per lakh population)	3	2	1
Population per police	172	306	752
Ratio of police budget to total state budget	0.07	0.05	0.03
Ratio of police training expenditure to total police expenditure	0.03	0.01	0.01
Transport facility per 100 police	13	8	12
Total vehicles at police stations to total police stations	19	19	12
Personal computers per police station	13	8	7
<b>Socio-economic variables</b>			
Number of schools (per lakh population)	966	346	97

Best case scenario Worst case scenario

Table 5. Cluster Profile – Partition 2 (Numbers denote averages for the variables for all states in the cluster)

Variables	Cluster 1	Cluster 2	Cluster 3
<b>Crime variables</b>			
Rape	41	853	2044
Assault on women with intent to outrage her modesty	61	1147	6154
Insult to modesty of women	7	51	502
Cruelty by husband or his relatives	38	1318	7161
<b>Police variables</b>			
Population per police	352	659	754
Ratio of police budget to total state budget	0.05	0.05	0.05
Transport facility per 100 police	13	12	12
Total vehicles at police stations to total police stations	19	12	12
Personal computers per police station	13	5	8
<b>Socio-economic variable</b>			
GDP growth rate	7.08	8.29	6.71

According to either of the partition,

- *Cluster 1*: LCG – States and union territories belong to Low Crime Group (lowest crime levels and show best values for socio-economic and police variables)
- *Cluster 2*: MCG – States belong to Medium Crime Group
- *Cluster 3*: HCG – States belong to High Crime Group (high crime levels and worst figures mostly for socio-economic and police variables).

Insights:

While profiling the clusters on the police and socio-economic variables some interesting traits are identified.

In Cluster 1 states average women police strength is inversely proportional to specific crimes against women. States where the police budget is higher and investments towards police training skills are more, the crime rates for those states show a negative trend. It is also observed that police infrastructure like police-vehicles, uses of computers and automation have direct impact on reducing crime rates. These states also have a higher number of schools.

B. Predictive modeling:

The outcome of multiple regression equations for all clusters is given in Table 6.

Table 6. Key predictors for crime

Partition	Cluster no.	Crime	R <sup>2</sup>	Key predictors	States in the cluster
Partition 1	1 (LCG)	Murder	0.37	Population per police station, population per school	Arunachal Pradesh, Goa, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, A&N Islands, Chandigarh, Daman Diu, Dadra & Nagar Haveli, Lakshadweep, Puducherry
	2 (MCG)	Robbery	0.68	Police budget to state budget, transport facility per hundred police, population per police training expenditure	Himachal Pradesh, Jammu & Kashmir, Punjab and Uttarakhand
		Dowry deaths	0.59	Population per police sub-division, population per police circles	
	3 (HCG)	Trespassing and burglary	0.65	Population per police zone, population per police station, police training expenditure and police budget	Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, West Bengal, Delhi
Partition 2	1 (LCG)	Rape	0.02	Women police per population and population per police range	Arunachal Pradesh, Goa, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Andaman and Nicobar Islands, Chandigarh, D&N Haveli, Daman and Diu, Lakshadweep and Puducherry
		Outrage to modesty of woman	0.03	Number of police vehicles and population per police range	
	2 (MCG)	Total crimes against women	0.67	Police budget to state budget, number of schools	Bihar, Chhattisgarh, Gujarat, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Punjab, Tamil Nadu, Uttarakhand
		Rape	0.79	Population per police zone, police budget to state budget, number of schools	
		Outrage to modesty of woman	0.66	Number of jails, population per police range	
	3 (HCG)	Outrage to modesty of woman	0.59	Women police to female population, population per police station	Andhra Pradesh, Assam, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Telangana, Uttar Pradesh, West Bengal, Delhi
		Trespassing and burglary	0.72	Police strength, number of police stations, number of police vehicles, police training budget	
		Total IPC crimes	0.58	Number of police vehicles, population per police range	
Theft		0.41	Police strength, police zones, police training to police budget expenditure		

Key takeaways from Table 6:

- 1) It is interesting to note that even for the same crime, such as ‘outrage to modesty of woman’, predictors may be different in different clusters.
- 2) Regression equations do not have similar predictive power in all clusters. Since the crime against women incidences are very low in cluster 1 of Partition 2, its predictability is also negligible.
- 3) One of the most important observation is that the number of schools is a key predictor for murder, rape and total crime against women.
- 4) Police coverage (viz. police zones, police range and police stations) and police infrastructure are key

predictors of crime incidences. Higher values of them are deterrent to crimes.

Setting up a robust education system, improving police infrastructure and strengthening of trained and mobile police force will curb specific crime incidences like murder, rape, dowry deaths etc., thereby making India safer and more business friendly.

#### IV. CONCLUSION

There is a strong need to monitor and analyse all the various types of crimes occurring across the country in addition to regulating them. The task of crime regulation is solely in the hands of the government. Frequent and in-depth analysis of crimes should be

carried out to derive conclusions, form opinion and suggest necessary actions. To enable this, analysis of the past crime database is critical. This data can play a significant role in helping the government take better informed decisions and act to maintain law and order.

Based on the clustering and the key predictors identified through the regression models, the following recommendations may be made:

- Government should take steps to increase the number of schools and other educational institutions for HCG states as the number of schools per lakh population in those states is very low compared to other clusters.
- Total police strength per lakh population in HCG states is far lower than that in LCG states. Hence, it is recommended to increase the police strength for HCG states.
- Total number of women police per lakh population in HCG states is less compared to that in LCG states. Steps need to be taken to increase the women police strength.
- With increase in police strength, efforts need to be put, to increase the number of police stations and their reach within states for HCG states.
- There is a need to improve the police infrastructure such as transport facilities, vehicles available in each police station and personal computers. . This will enhance police productivity and boost the operations of police force to a good extent.

Detailed analysis of model outcomes also suggests that there are a few influencing parameters which are common across various types of crimes in bigger states having relatively large area and population. On the other hand, there are few other indicators which can help control specific crimes in smaller states, e.g., increase the share of police budget in the state budget, focus on police training and strengthening overall police infrastructure. This can help curb crimes like burglary, trespassing and theft in states like Andhra Pradesh, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, West Bengal, Kerala and Delhi. For various north-eastern states and union territories, increase in women police force can inhibit rape cases and expansion of basic education facilities can address crime like murder.

The data set used for this research has been limited to five-year period and at state level. As a result, the recommendations are given at a broad state level. This model has the potential to carry out crime analysis, clustering and prediction beyond five-year horizon and cover smaller geographic areas such as districts and cities.

However, apart from the crimes mentioned in this study there are other heinous crimes like terrorism, smuggling, animal poaching etc. To prevent any such crime, it is important to understand the pattern and criminal behaviours. Advanced machine learning techniques like Natural Language Processing (NLP), text analytics or other data mining tools can be used, where feed from various communication networks, social media interactions, CCTV footages etc. can be considered to analyse human behaviours and real time prediction of crimes.

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