

# **PREDICTIVE ANALYTICS FOR LAW ENFORCEMENT AGENCIES**

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**PREDEICTIVE ANALYTICS FOR LAW  
ENFORCEMENT AGENCIES**

*by*

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*Submitted*

*in fulfillment of the requirements for the degree of Doctor of Philosophy*

*to the*



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*Dedicated to My Family*

# CERTIFICATE

This is to certify that the thesis titled “**Predictive Analytics for Law Enforcement Agencies**” being submitted by Mr. Rajkuamr Vishwakarma (Entry No. 2013SMZ8602) to the Department of Management Studies, Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy (Ph.D.) is a record of bona fide research work carried out by him. He has worked under my guidance and supervision, and has fulfilled the requirements for the submission of this thesis, which has attained the requisite standard for Ph.D. degree from the Indian Institute of Technology Delhi. The results presented in the thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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**Rajkumar Vishwakarma**

# ABSTRACT

Law enforcement agencies across the globe face the pressure of improving citizen services with minimum resource and limited logistics support. Quantitative revolution is making various fields of social sciences more meaningful to anthropogenic world. More accurate predictions with general rules and hypothesis are being derived. This thesis investigates application of quantitative techniques and artificial intelligence tools in accurate detection of crime hotspots and other aspects of police functioning.

Extensive literature review has been conducted from the perspective of crime patterns, criminological theories, crime concentration, distance decay, data mining, criminal behaviour, criminal network and application of ontology in crime criminal domain. Research gaps have been identified and three broad research objectives of crime pattern study, prediction of criminal behaviour and impact of demographic variables over crime have been identified. For this research quantitative models have been used and results have been discussed. Sensitivity analysis and parameter tuning of models have also been provided.

Police emergency management system has call takers, despatchers and GPS fitted patrol cars, connected to the centre for attending all kinds of distress calls. The research domain and the dataset are taken for Uttar Pradesh (UP), which is the largest populated state of India. UP Police, in India, has 4009 patrol cars, having 500 call takers and 250 despatchers, catering to 230 million people and has handled 4.48 million events in year 2017. The dataset used in this research is mainly for this setup. The state of UP has extensive criminal intensity. Reduction of this crime intensity is also the motive of this research.

Crime pattern study focuses on prediction of future hotspots, inter-crime correlation and geographical beat clustering. Kernel density function of crime is dependent on space, time, event type and impact of event. Crime data has trend, seasonality, chaos and randomness. Using research study of crime data of last 120 years of UP Police, we show supremacy of Neuro-fuzzy-GARCH technique for future hotspot prediction. RMS errors for different approaches have been calculated. For studying interdependence aspect of

crime pattern, linear regression technique has been used. For examining geographical beat clustering, as part of crime pattern study, Fuzzy c-means clustering has been used for logistics planning of patrol cars. Reasons for selection of model have also been discussed.

Further for accomplishment of the next objective, expert system has been designed, which can predict recidivist criminal behaviour. Model based on Neuro-fuzzy engines can predict probability of commission of repeat offences.

For investigating the next objective of conducting impact analysis of demographic parameters, Fuzzy-ISM model has been used that considers effect of agricultural, industrial, service sector growth and literacy over crime. In Indian context, agricultural growth has maximum impact over crime reduction.

At last, thesis examines key research findings, contributions and implications of research for academics and practitioners. Once hotspots are identified, mitigation strategy for sensitivity reduction are also analyzed. Geographical clustering of patrol cars will help in correct deployment of manpower, weapons, density of patrol cars and women police officers to prevent crime against women. Limitations of unstructured data, data volume, velocity and variety, missing values, and unreliability of many witnesses have been flagged. Scope for future research has been discussed.

## सार

दुनिया भर में कानून प्रवर्तन एजेंसियां न्यूनतम संसाधन और सी मत रसद सहायता के साथ नागरिक सेवाओं में सुधार के दबाव का सामना करती हैं। मात्रात्मक क्रांति, सामाजिक विज्ञान के विभिन्न क्षेत्रों को अधिक सार्थक बना रही है। सामान्य नियमों और परिकल्पना के साथ अधिक सटीक भविष्यवाणियां की जा रही हैं। इस शोध में, अपराध के आकर्षण के केंद्र और पुलिस कार्यप्रणाली के अन्य पहलुओं की सटीक पहचान में मात्रात्मक तकनीकों और 'AI' तकनीक के प्रयोग की जांच की गई है।

अपराध पैटर्न, अपराध सद्धान्तों, अपराध एकाग्रता, दूरी क्षय, डेटा खनन, अपराध व्यवहार, अपराध नेटवर्क और अपराध अपराध डोमेन में आंटलॉजी के प्रयोग, इत्यादि पर व्यापक साहित्य समीक्षा प्रेषित की गई है। अनुसंधान अंतराल की पहचान की गई है। उक्त शोध में तीन अनुसंधान उद्देश्यों की पहचान की गई है जो अपराध पैटर्न का अध्ययन, अपराध व्यवहार की भविष्यवाणी और अपराध पर जनसांख्यिकीय चर के प्रभाव से सम्बन्धित है। इस शोध के लिए मात्रात्मक मॉडल का उपयोग किया गया है और परिणामों पर चर्चा की गई है। मॉडल का संवेदनशीलता विश्लेषण और पैरामीटर ट्यूनिंग भी प्रदान किया गया है।

पुलिस आपातकालीन प्रबंधन प्रणाली में सभी प्रकार के संकट कॉल के प्रबंधन के लिए केंद्र से जुड़े कॉल टेकर, डिस्पैचर और जीपीएस सज्जित गश्ती कारें हैं। अनुसंधान से सम्बंधित डेटासेट उत्तर प्रदेश (यूपी) से लिया गया है, जो भारत का सबसे बड़ा आबादी वाला राज्य है। भारत में यूपी पुलिस के पास 4009 गश्ती कारें, 500 कॉल टेकर और 250 डिस्पैचर हैं। इनके द्वारा 230 मलयन लोगों के लिए पुलिस सेवाएं प्रदान की जाती हैं। इनके द्वारा वर्ष 2017 में 4.48 मलयन घटनाओं में सहायता प्रदान किया गया है। इस शोध में प्रयुक्त डेटासेट मुख्य रूप से इस सेटअप के लिए है। यूपी राज्य में अपराध तीव्रता अधिक है। इस अपराध की तीव्रता में कमी भी इस शोध का उद्देश्य है।

अपराध पैटर्न अध्ययन, भविष्य के 'अपराध हॉटस्पॉट' के केंद्र, अंतर-अपराध सहसंबंध और भौगोलिक बीट क्लस्टरिंग की भविष्यवाणी पर केंद्रित है। अपराध का कर्नेल घनत्व क्षेत्र, समय, घटनाओं के प्रकार व प्रभाव पर निर्भर करता है। अपराध डेटा में 'trend', 'seasonality', 'chaos', और 'randomness' है। यूपी पुलिस के पहले 120 वर्षों के अपराध आंकड़ों के अनुसंधान अध्ययन का उपयोग करते हुए, हमारे द्वारा भविष्य के हॉटस्पॉट भविष्यवाणी के लिए न्यूरो-फ़ज़ी-गार्च तकनीक का वर्चस्व दिखाया गया है। विभिन्न दृष्टिकोणों के लिए 'RMS

error' की गणना की गई है। अपराध पैटर्न के व भन्न पहलुओं का अध्ययन करने के लए, रै खक प्रतिगमन तकनीक का उपयोग कया गया है। अपराध पैटर्न अध्ययन के भाग के रूप में भौगोलक बीट क्लस्टरिंग की जांच के लए, 'Fuzzy c-means clustering' का उपयोग कया गया है। मॉडल के चयन के कारणों पर भी चर्चा की गई है।

अगले उद्देश्य की स द्ध के लए, वशेषज्ञ प्रणाली को डजाइन कया गया है, जो क पुनरावर्ती आपरा धक व्यवहार की भ वष्यवाणी कर सकता है। न्यूरो-फ़ज़ी इंजन पर आधारित मॉडल पुनरावृत्ति अपराधों की आयोग की संभावना का अनुमान लगा सकता है।

जनसांख्यिकीय मापदंडों के प्रभाव वश्लेषण के अगले उद्देश्य की जांच के लए, फ़ज़ी-आईएसएम मॉडल का उपयोग कया गया है जो अपराध पर कृ ष, औद्योगक, सेवा क्षेत्र की वृ द्ध और साक्षरता के प्रभाव पर वचार करता है। भारतीय संदर्भ में, कृ ष के वकास का अपराधो की कमी पर अ धकतम प्रभाव है।

अंत में, शोध में प्रमुख अनुसंधान निष्कर्षों, योगदान और शक्षा वदों और पु लस वभाग के लए अनुसंधान के उपयो गता पर प्रकाश डाला गया है। एक बार हॉटस्पॉट की पहचान हो जाने के बाद, संवेदनशीलता में कमी के लए शमन रणनीति का भी वश्लेषण कया जाता है। गश्ती कारों की भौगोलक क्लस्टरिंग से महिलाओं के वरुद्ध अपराध को रोकने के लए जनशक्ति, ह थयार, गश्ती कारों के घनत्व और महिला पु लस अ धकारियों की सही तैनाती में मदद मलेगी। अंत में असंर चत डेटा, डेटा की मात्रा, वेग और व वधता, अनुपस्थित मान, और कई गवाहों की अ वश्वसनीयता आदि की सीमा पर प्रकाश डाला गया है। भ वष्य के अनुसंधान के लए स्कोप पर भी चर्चा की गई है।

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# ABBREVIATIONS

<b>AI</b>	Artificial Intelligence
<b>ANFIS</b>	Adaptive Neuro-Fuzzy Inference System
<b>ANPR</b>	Automatic Number Plate Recognition System
<b>ATS</b>	Anti-Terrorist Squad
<b>BBN</b>	Bayesian Belief Network
<b>BPNN</b>	Back Propagation Neural Network
<b>C4iSR</b>	Command, Control, Communication, Computer, Intelligence, Surveillance and Reconnaissance
<b>CSF</b>	Critical Success Factor
<b>CFS</b>	Call for Service
<b>DSS</b>	Decision Support System
<b>DV</b>	Dependent Variable
<b>GARCH</b>	Generalized Autoregressive Conditional Heteroscedasticity
<b>GPS</b>	Global Positioning System
<b>ICT</b>	Information and Communication Technology
<b>ISM</b>	Interpretive Structural Modelling
<b>IV</b>	Independent Variable
<b>KPI</b>	Key Performance Indicators
<b>MICMAC</b>	Matriced' Impacts Croise's Multiplication Appliquée a UN Classement (Impact Matrix Cross- Reference Multiplication Applied to a Classification)
<b>NANP</b>	North American Numbering Plan
<b>NYCRI</b>	New York City RAND Institute
<b>NCRB</b>	National Crime Record Bureau
<b>PART</b>	Projective Adaptive Resonance Theory
<b>RDBMS</b>	Relational Database Management System

<b>RDF</b>	Resource Description Framework
<b>RMS</b>	Root Mean Square
<b>SFADC</b>	Semantic Analysis of Digital Forensic Cases
<b>SPSS</b>	Software Package for Statistical Analysis
<b>STF</b>	Special Task Force
<b>STSD</b>	Secondary Traumatic Stress Disorder
<b>USA</b>	United States of America