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Forensic Technology and Its Contribution to Criminal Justice Administration

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Abstract

Forensic technology has become an indispensable component of modern criminal justice administration by enhancing the accuracy, efficiency, and reliability of criminal investigations. Scientific techniques such as DNA profiling, fingerprint analysis, digital forensics, cyber forensics, ballistics, toxicology, and forensic pathology assist in identifying offenders, securing convictions, and preventing wrongful convictions. In India, the growing importance of forensic science is reflected in legislative developments, including the Bharatiya Sakshya Adhinyam, 2023, and increasing judicial reliance on scientific evidence. However, challenges such as inadequate infrastructure, shortage of experts, privacy concerns, and ethical issues continue to affect its effective implementation. This paper examines the evolution, significance, legal framework, challenges, and future prospects of forensic technology in strengthening criminal justice administration.

Keywords: *Forensic Technology, Criminal Justice Administration, Forensic Science, DNA Profiling, Digital Forensics, Cybercrime, Biometrics, Scientific Evidence, Bharatiya Sakshya Adhinyam 2023, Criminal Investigation, Privacy Rights, Artificial Intelligence.*

Introduction

Criminal justice administration has changed dramatically with the evolution of forensic technology. Historically, criminal investigations have been based on the testimony of witnesses, the confession of the suspect, and circumstantial evidence. These approaches have had limitations as they were prone to inaccuracies, bias, coercion, and mistakes by law enforcement personnel. The introduction of forensic science into criminal investigations allowed for applying scientific methods to ensure that criminal justice administration is based on verifiable and scientifically accurate data.¹ Forensic technology has become an essential element of modern criminal justice systems, improving the quality of investigations and ensuring procedural justice.

Forensic technology involves the application of various sciences and technologies to support criminal investigations, identification of perpetrators, and their prosecution in court. The main types of forensic technologies include DNA profiling, fingerprint analysis, digital forensics, cyber forensics, forensic toxicology, ballistic science, forensic pathology, facial recognition technologies, and artificial intelligence solutions.² Criminal investigations are now more complex than ever before due to technological advancements in the sphere of terrorism, cybercrime, organized crime, and financial crime.³

Forensic technology's application is not limited to the detection of criminals. The introduction of scientific evidence has helped in maintaining justice in criminal trials, making use of confessions and witness statements less significant since both can be unreliable at times. For example, DNA evidence has helped in convicting serious criminals and has also led to the exoneration of many innocents wrongly accused of crimes.⁴

In the case of India, the significance of forensic technology has increased dramatically over the past twenty years. Technological advancements in the police force, the rise of cybercrime, and the requirement for scientific examination by the judiciary have made forensic techniques more important than ever before.⁵ The Indian judiciary has always emphasized the use of scientific evidence in criminal investigations, especially in cases of sexual crimes, terrorism, murders, and

¹Larry J Siegel, *Criminology: Theories, Patterns and Typologies* (13th edn, Cengage Learning 2018).

² Richard Saferstein, *Forensic Science: From the Crime Scene to the Crime Lab* (3rd edn, Pearson 2017).

³ Susan W Brenner, *Cybercrime and the Law: Challenges, Issues and Outcomes* (Northeastern University Press 2012).

⁴ Brandon L Garrett, *Convicting the Innocent* (Harvard University Press 2011).

⁵K I Vibhute and P S Mani, *Criminal Justice Administration* (LexisNexis 2019).

cybercrimes.⁶ The passing of the Bharatiya Sakshya Adhiniyam, 2023, is another indication of the importance of forensic evidence in Indian criminal jurisprudence.⁷

Nevertheless, there still exist numerous obstacles which inhibit the efficient application of forensic technology. Forensic infrastructure deficiencies, lack of experts, delays during lab examinations, insufficient chain-of-custody measures, and ethical issues pertaining to privacy and surveillance constitute significant obstacles.⁸ Furthermore, the increasing deployment of facial recognition technologies, biometric databases, and artificial intelligence has raised important issues in terms of citizens' civil liberties and rights.⁹ Therefore, while forensic technology is crucial to the functioning of criminal justice administration, at the same time it requires proper legal and ethical regulation.

This paper provides a critical analysis of the importance of forensic technology for modern criminal justice administration. Specifically, it addresses the issue of forensic technology development, main areas of forensic technology, practical importance of forensic technology, legislative framework for forensic technology application, major problems related to forensic technology application, and future prospects associated with the development of forensic technology.

Forensic Science Evolution within Criminal Justice Administration

The emergence of forensic science can be associated with early civilizations wherein there was some degree of scientific practice employed in determining cause of death and identifying the perpetrators.¹⁰ However, modern forensic science was only introduced towards the end of the nineteenth century through scientific police and criminology. This included the use of fingerprinting identification pioneered by Sir Francis Galton and Alphonse Bertillon's use of anthropometry which radically changed methods of crime investigation.¹¹

This era was marked by the professionalization of forensic science through the creation of forensic laboratories, medico-legal sections and scientific investigation teams.¹² Ballistics, blood groupings, toxicology and handwriting were gradually becoming recognized types of evidence in legal

⁶ *State of Bombay v Kathi Kalu Oghad* AIR 1961 SC 1808.

⁷ Bharatiya Sakshya Adhiniyam, 2023

⁸ Madhava Menon, *Forensic Science and Criminal Justice in India* (Eastern Book Company 2020)

⁹ Andrew Ferguson, *The Rise of Big Data Policing* (NYU Press 2017)

¹⁰ Henry Lee and R E Gaensslen, *Advances in Fingerprint Technology* (CRC Press 2001)

¹¹ Simon Cole, *Suspect Identities* (Harvard University Press 2001).

¹² Barry Fisher, *Techniques of Crime Scene Investigation* (CRC Press 2012)

proceedings. Improvements in forensic medicine also greatly contributed to better crime investigations through precise identification of causes of death and injury.¹³

Another revolutionary aspect of forensic science was the invention of DNA profiling by Sir Alec Jeffreys in 1984.¹⁴ DNA technology transformed crime investigations by allowing for the identification of suspects using biological evidence in an extremely precise manner. DNA profiling became one of the most accurate forensic technologies that have been widely used in investigating homicides, sexual crimes, identifying victims of disasters, and even solving paternity issues.¹⁵

The advent of the digital age led to another technological transformation in crime investigations. With the increased reliance on computers, cellphones, cloud storage systems, and Internet communication, criminal activities such as hacking, cyberterrorism, fraud schemes, identity theft, and electronic espionage came into existence.¹⁶ Digital forensics thus developed into a separate discipline concerned with obtaining electronic information and conducting its thorough examination.¹⁷

Forensic science in India grew in stages after the country gained its independence with the development of forensic laboratories. The Central Forensic Science Laboratory and many forensic science laboratories in states played an important role in criminal investigations.¹⁸ The creation of the National Forensic Sciences University proved to be crucial for advancing forensic sciences education and research. Judicial pronouncements and legislation have focused more and more on scientific evidence in criminal cases.¹⁹

Main Branches of Forensic Science

- **DNA Typing and Biological Evidence**

DNA typing has been considered one of the most revolutionary breakthroughs in the field of forensic science because it allows researchers to accurately identify individuals with a high level of certainty. Deoxyribonucleic acid (DNA) is a substance that is found uniquely in every person other than

¹³ Bernard Knight, *Forensic Pathology* (CRC Press 2016)

¹⁴ Alec Jeffreys, 'DNA Fingerprinting' (1985) 316 *Nature* 76.

¹⁵ John Butler, *Forensic DNA Typing* (Elsevier 2015)

¹⁶ Eoghan Casey, *Digital Evidence and Computer Crime* (Academic Press 2011)

¹⁷ Marjie Britz, *Computer Forensics and Cyber Crime* (Pearson 2013)

¹⁸ Central Forensic Science Laboratory Annual Report 2022

¹⁹ *Selvi v State of Karnataka* (2010) 7 SCC 263.

identical twins. Biological specimens such as blood, saliva, semen, hair roots, bones, body fluids, and skin tissues are usually analyzed using DNA technology.²⁰

The importance of DNA typing in criminal justice cannot be understated. In criminal investigations involving murder and sexual assault cases, DNA helps identify the perpetrator and rule out innocent people. Courts have increasingly come to consider DNA as extremely reliable evidence because of its objectivity and scientific validity. The DNA technology has been used in freeing many wrongly accused persons who were found guilty of their crimes based on false eyewitness testimony or coercive confession.²¹

The use of DNA testing goes beyond traditional criminal investigations. It is widely used in mass disasters, identifying missing people, paternity cases, and human trafficking investigations.²² In situations involving mass disasters like terrorism, natural disasters, and wars, forensic scientists rely on their DNA databases for determining the identity of victims who could have suffered extensive injuries.²³

The use of DNA technology has gained significance in criminal trials in India, especially in cases of rape and murder.²⁴ The courts have acknowledged that DNA testing is scientific and credible if the samples are collected, preserved, and documented in accordance with the appropriate protocols. Nonetheless, issues related to privacy, the misuse of genetic information, and lack of DNA laws persist.

- **Forensic Fingerprinting and Biometrics**

Fingerprints have been considered among the most well-established branches of forensic science. Since fingerprints are highly unique and relatively permanent, they can be used for individual identification. Fingerprints of no two individuals match one another, and they do not change during one's lifetime.²⁵ Therefore, fingerprints play a central role in criminal investigations around the globe.

Computerization through Automated Fingerprint Identification Systems (AFIS) has led to efficient administration of criminal justice procedures. The process entails searching for fingerprints gathered

²⁰ Alec Jeffreys, 'DNA Fingerprinting' (1985) 316 Nature 76

²¹ David Balding, *Weight-of-Evidence for Forensic DNA Profiles* (Wiley 2005)

²² John Butler, *Advanced Topics in Forensic DNA Typing* (Elsevier 2011).

²³ United Nations Office on Drugs and Crime, *Handbook on DNA for Criminal Justice Systems* (2019)

²⁴ *Mukesh v State (NCT of Delhi)* (2017) 6 SCC 1.

²⁵ Simon Cole, *Suspect Identities* (Harvard University Press 2001)

from crime scenes against millions of entries stored in databases within very short periods. Fingerprints are especially important in cases of burglary, robbery, homicides, and terroristic acts.

Contemporary biometric forensics is not restricted to fingerprint analysis but includes iris recognition, retinal scan, facial recognition, palm print, and voice recognition systems. Biometrics are applied in border security, surveillance systems, airport security systems, and criminal databases. The application of facial recognition technology, for instance, allows law enforcement officers to recognize suspects using CCTV images and other forms of digital images.

Although biometric surveillance offers various advantages, there are significant issues associated with such surveillance techniques, especially in relation to privacy and human rights considerations. State surveillance through facial recognition technology could violate the privacy and dignity of people as well as their right to move freely within the country. There are also claims that biometric surveillance could target certain marginalized groups and cause technological discrimination.²⁶

- **Digital and Cyber Forensics**

The advent of the digital age has revolutionized not only criminal activity but also criminal investigation. Digital forensics involves the scientific process of acquiring, preserving, analyzing, and presenting electronic evidence acquired from computers, mobile phones, servers, clouds, digital networks, and other storage devices.²⁷ Since modern-day communication and financial transactions have shifted towards digital formats, it has become vital for criminal justice management processes today.

Cyber forensics involves the investigation of crimes carried out by using digital means. Hacking, cyber-terrorism, phishing, identity theft, ransomware attacks, online frauds, cyber-stalking, crypto-currency frauds, and child pornography are a few examples of cybercrimes. Investigators use specialized software to recover deleted files, track IP addresses, investigate browsing history, decrypt data, analyze metadata, and recreate digital activities.²⁸

The significance of digital forensics has seen a significant rise owing to social media, cloud computing, secure communication methods, and crypto-currencies. In most criminal cases, cell phones and computers hold valuable information pertaining to communications, location, financial

²⁶ Cathy O’Neil, *Weapons of Math Destruction* (Penguin 2016)

²⁷Eoghan Casey, *Digital Evidence and Computer Crime* (Academic Press 2011)

²⁸ Marjie Britz, *Computer Forensics and Cyber Crime* (Pearson 2013)

transactions, and criminal planning. Experts specializing in digital forensics often serve an important purpose during terrorism investigations owing to the use of encrypted internet networks by extremist groups.²⁹

Electronic records have also found their way into Indian courts. According to the Bharatiya Sakshya Adhiniyam, 2023, electronic records such as emails, digital documents, CCTV footage, and digital communication have attained legal significance. Nonetheless, issues surrounding data manipulation, cybersecurity, encryption problems, and evidentiary requirements persist to hinder digital forensics operations.

The issue of the interplay between cyber investigation and the constitutional right to privacy is another crucial concern. Surveillance conducted through the digital domain by the state might compromise individual freedom and democracy. Consequently, digital forensics must be monitored by the judiciary.

- **Ballistics and Ballistic Tests on Firearms**

Ballistics is a unique specialization within forensics that deals with the scientific investigation of weapons, ammunition, projectiles, shooting residues, and ballistics.³⁰ This field is extremely valuable for solving cases involving homicide, organized crime, terrorism, and other forms of firearm violence.

Ballistic experts conduct tests to identify whether a certain weapon had been involved in the commission of the crime. The firing of any weapon produces unique microscopic marks on bullets and cartridges. By conducting ballistic comparisons, it is possible to find out whether a particular bullet has been shot from a specific gun.

Gunshot residue examination is an equally valuable method for ballistic testing. The chemical residue resulting from the use of firearms may be found on the hands and clothes of the suspects or in the surrounding environment.³¹ In the laboratory, experts test such residues to find out whether the person fired a weapon.

Moreover, trajectory analysis enables the police to ascertain the direction, angle, and range of the shots fired. Scientific recreation helps to establish more accurate evidence that assists in the judicial determination of criminal responsibility.

²⁹ Clough (n 23)

³⁰ Vincent Di Maio, *Gunshot Wounds* (CRC Press 2015)

³¹ Barry Fisher, *Techniques of Crime Scene Investigation* (CRC Press 2012)

The use of ballistic forensics has gained prominence in tackling terrorist activities and organized crimes. For instance, in cases of transnational terrorism, ballistics analysis of the weapon and explosive devices can aid in determining the source of the illegal arms pipeline. Nonetheless, ballistic evidence may be fallible at times, especially when forensic investigation methods are incorrectly applied. Hence, the court should carefully analyze any expert opinions on firearms.

- **Forensic Toxicology**

Forensic toxicology refers to the scientific study of the identification of toxic substances, drugs, alcohol, poisons, and chemicals in the body. It plays a key role in the investigation of poisoning, unnatural deaths, crimes involving narcotic drugs, impaired drivers, and substance abuse cases.

The work of the toxicologist involves analysing the blood, urine, hair, tissue, and body fluids for the presence of toxic substances. The analysis often helps the forensic pathologist establish the cause of death and the criminal act. In the case of murder by poison, the forensic toxicologist can provide scientific proof that connects the suspect with the crime.

The growing number of synthetic drugs, drug trafficking, and chemical poisoning incidents has increased the necessity of toxicology studies in criminal justice. Sexual assault cases that involve sedatives and intoxicating substances are often reliant on toxicology studies for successful prosecutions.³²

The field of forensic toxicology is also essential in road safety law enforcement by conducting alcohol and drug tests on impaired drivers. Through scientific study, it becomes possible to establish whether intoxication was a contributing factor to reckless and criminal activities.

Although it is highly significant, the science of forensic toxicology is not without its difficulties such as laboratory processing, contamination, and complexities in interpreting chemical reactions. Moreover, new synthetic substances are difficult to detect due to the rapid evolution of narcotics markets.³³

- **Forensic Pathology and Medico-Legal Investigation**

³² World Health Organization, *Global Status Report on Road Safety* (2023)

³³UNODC World Drug Report (n 44)

Forensic pathology is focused on establishing the cause and manner of death through medical analysis of the dead. Forensic pathologists perform autopsies in order to determine the nature of injuries, diseases, poisons, or physical anomalies that lead to death. This field of study forms an integral component of homicide investigations since it helps differentiate between deaths due to natural causes, accidents, suicides, and murders.

Autopsy results sometimes prove to be vital clues regarding the time of death, types of injuries, weapons used, and events leading to murder. The forensic pathologist is also useful to the police during investigations of custodial abuse, torture, sexual abuse of children, and domestic violence.³⁴

In contemporary criminal justice administration, medico-legal investigation is indispensable when dealing with rape cases. A proper medical examination of the victim may yield valuable evidence for use during court proceedings.

Forensic pathology is applied to humanitarian issues such as wars, genocides, and mass disasters. Forensic pathologists play an essential role in international criminal proceedings, providing evidence for war crimes, mass murders, and other crimes against humanity.³⁵

Nevertheless, there are problems within the practice of forensic pathology, namely, lack of professional staff, unsatisfactory autopsy rooms, and political pressure in controversial cases.⁵⁷ The lack of proper medico-legal support system in some regions leads to improper criminal proceedings and wrongful convictions.

- **Forensic Psychology and Behavioral Science**

Forensic psychology refers to the field of knowledge at the intersection of psychology and criminal justice administration.³⁶ It concentrates on analyzing criminal behavior, mental disorders, witnesses psychology, victim traumatology, and behavioral traits related to the criminal acts.

Forensic psychologists provide support for investigations by applying profiling, competency assessment, risk evaluation, and psychological examination of offenders. The use of behavioural profiling is particularly valuable in solving serial crimes, where psychological traits can be helpful in predicting probable perpetrators.

Another key point about forensic psychology lies in conducting evaluation of the reliability of witnesses' testimonies and confessions. As shown by psychological researches, memory distortions,

³⁴ *D.K. Basu v State of West Bengal* (1997) 1 SCC 416

³⁵ Rome Statute of the International Criminal Court 1998

³⁶ Bartol and Bartol, *Introduction to Forensic Psychology* (Sage 2018)

psychological pressure on victims, coercive interrogations, and suggestive interviewing can negatively impact these statements. Thus, forensic psychology promotes fairness in investigations.

Additionally, forensic psychologists provide essential assistance in juvenile justice management, correction of prisoners, rehabilitation programs, and counseling for victims. It helps judges make decisions related to criminal liability, mental incompetence, and the possibility of rehabilitation.

However, forensic psychology raises certain controversies in some spheres, as behavior forecasting may sometimes be scientifically inaccurate. Moreover, there exist issues of ethics, related to possible manipulation of people during investigation.

Significance of Forensic Technology in Criminal Justice Administration

Forensic technology is highly significant in criminal justice administration, for it transforms the field. Firstly, forensic technology enhances the accuracy and reliability of criminal investigations. Scientific evidence makes reliance on custodial confessions and eyewitness testimonies less critical and helps prevent wrongful convictions.

Secondly, forensic technology boosts the efficiency of criminal investigations. Technological advancements have allowed law enforcement agencies to analyze evidence quickly and reconstruct crime scenes, and identify suspects efficiently.

Thirdly, forensic technology provides judges with factual information that is easier to verify and prove objectively. Judges tend to take into consideration scientific evidence more than statements made by witnesses, since such evidence is not affected by memory distortions and is less prone to coercion and manipulation.

Fourthly, forensic technology is an important part of human rights protection in the sphere of criminal justice administration. The risk of torture-based investigations becomes lower, since the police increasingly uses evidence gained through technological means.³⁷ Numerous cases of DNA exonerations across the world show that forensic science is very helpful in solving crimes.

Challenges and Ethical Dilemmas

Notwithstanding its numerous strengths, the forensic technology also poses certain challenges and ethical dilemmas. First, there is a problem of insufficient forensic capacity. As noted earlier, in India,

³⁷ *D.K. Basu v State of West Bengal* (1997) 1 SCC 416

forensic laboratories usually lack qualified staff, proper facilities, and promptness in report submission. All these factors adversely affect the quality of criminal proceedings.

Moreover, there is always a risk of potential scientific mistakes and contamination. If not collected and processed appropriately, forensic evidence will yield incorrect results. Therefore, courts need to ensure that all procedures are strictly followed.

Furthermore, new methods like biometrics, DNA banks, facial recognition techniques, and artificial intelligence have raised many privacy issues. Too much surveillance threatens people's constitutional rights to privacy, human dignity, and personal liberty. Indeed, in the landmark case of Justice K. S. Puttaswamy v. Union of India, the Supreme Court of India has declared privacy as a fundamental right under the Indian Constitution, thus placing constitutional limits on state surveillance practices.

Technological discrimination is another ethical concern. The artificial intelligence software used for predictive policing could end up targeting oppressed groups based on how it was programmed through the use of a biased dataset.³⁸ For this reason, efficiency should not take precedence over equality, justice, and fairness.

Legal Provisions Regarding Forensic Evidence in India

The provisions governing forensic evidence in India can be found in the Bharatiya Sakshya Adhinyam, 2023, which superseded the Indian Evidence Act, 1872.³⁹ The significance of electronic evidence, opinion evidence, forensic DNA analysis, and digital evidence is now increasing day-by-day in criminal cases.

Provisions pertaining to expert testimony consider forensic experts such as medico-legal experts, ballistic experts, fingerprints experts, and digital forensics experts. Forensic evidence is normally admitted in court if certain scientific tests and evidentiary standards are followed.

Reforms under the Code of Criminal Procedure along with judicial directions have also helped in improving the scientific investigation process. In sexual offence cases, forensic DNA analysis becomes crucial.⁴⁰ Likewise, in cybercrime cases, electronic and digital evidence play a crucial role.

In India, the courts have always stressed the need for scientific examination. The Supreme Court of India considered the constitutionality of using narco-analysis, polygraph test, and brain-mapping

³⁸ Cathy O'Neil, *Weapons of Math Destruction* (Penguin 2016)

³⁹ Bharatiya Sakshya Adhinyam, 2023

⁴⁰ Criminal Law (Amendment) Act 2013

methods in the case of *Selvi vs State of Karnataka*.⁴¹ The Court found that use of these methods without the consent of the suspect violated his/her fundamental right against self-incrimination guaranteed by Article 20(3).⁴²

Conclusion

Forensic science has played an instrumental role in bringing about a paradigm shift in modern-day criminal justice administration, bringing about scientific precision and technology into the investigative and judicial processes. Whether it is DNA fingerprinting, digital forensics, cyber investigation, or biometric authentication, the significance of forensic science in modern times is immense. Scientific evidence helps in ensuring that criminal proceedings become more reliable, reducing the need for unreliable confessions and subjective witness statements.

While in India, the rising significance of forensic science can be attributed to the many changes taking place in the realm of criminal justice administration, there are various factors that have to be considered, such as the lack of proper infrastructure, shortage of professionals, ethics, privacy issues, and concerns regarding civil liberties.

Nevertheless, it is certain that the future of criminal justice administration would depend upon the proper utilization of scientific advancements; however, technology alone cannot ensure justice.

⁴¹*Selvi v State of Karnataka* (2010) 7 SCC 263

⁴² *ibid*