



FORENSIC SCIENCE IN CRIMINAL INVESTIGATIONS: ADMISSIBILITY, RELIABILITY, AND PROCEDURAL DELAYS

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ABSTRACT

Forensic science has emerged as an indispensable pillar of modern criminal investigations, transforming the administration of justice from subjective eyewitness testimony toward objective, scientifically validated truth-seeking. By bridging the gap between empirical science and legal adjudication, forensic disciplines—ranging from DNA profiling and digital forensics to ballistic analysis and forensic pathology—provide courts with the evidentiary precision necessary to convict the guilty and exonerate the innocent. However, the integration of forensic science into criminal justice systems frequently encounters complex challenges concerning evidentiary admissibility, scientific reliability, and severe procedural delays. This comprehensive article evaluates the evolving role of forensic science in criminal investigations, adopting a constructive, forward-looking perspective that highlights remarkable technological advancements and the years preceding it. By examining landmark judicial precedents, statutory reforms such as the enactment of the Bharatiya Nagarik Suraksha Sanhita (BNSS), 2023, and advancements in forensic infrastructure, this study explores how legal and scientific communities are actively collaborating to overcome backlogs and enhance reliability. Ultimately, the paper argues that continuous technological innovation, mandatory accreditation of forensic laboratories, and streamlined procedural protocols will foster a robust, transparent, and highly efficient criminal justice ecosystem.

1. INTRODUCTION

The pursuit of justice in a democratic society depends upon the integrity, accuracy, and scientific rigor of criminal investigations. Historically, criminal trials relied heavily on testimonial evidence, confessions, and circumstantial clues, which, while valuable, were inherently vulnerable to human error, coercion, and subjective bias. The advent and maturation of forensic science revolutionized this landscape by introducing objective, empirical methods to reconstruct crime scenes, identify perpetrators, and establish the chronological sequence of criminal acts. From Locard's fundamental exchange principle—stipulating that every contact leaves a trace—to advanced molecular biology and digital forensics, science has empowered investigators to unlock secrets hidden within microscopic physical evidence.

In recent decades, particularly leading , the Indian criminal justice system has witnessed a progressive paradigm shift toward scientific investigation. Recognizing that traditional investigative methods often lead to high acquittal rates and systemic delays, legislators, jurists, and forensic experts have championed sweeping reforms to modernize crime scene management and evidentiary evaluation. The transition from colonial penal statutes to contemporary legislative frameworks—culminating in landmark criminal law overhauls—reflects a positive, proactive commitment to embedding scientific rigor directly into the statutory text.

This article examines the multifaceted role of forensic science in criminal investigations. It evaluates the legal criteria governing evidentiary admissibility, explores the standards of scientific reliability, addresses historical and ongoing efforts to mitigate procedural delays, and celebrates the transformative

technological milestones achieved .

2. THE LEGAL ARCHITECTURE OF FORENSIC ADMISSIBILITY AND RELIABILITY

For scientific evidence to influence judicial outcomes, it must satisfy stringent legal tests of admissibility and reliability, ensuring that courts rely only on validated, scientifically sound methodologies.

2.1 Evidentiary Admissibility under Statutory Frameworks

Under traditional Indian evidence law (governed historically by the Indian Evidence Act, 1872, and reinforced by the Bharatiya Sakshya Adhiniyam, 2023, effective from July 2024), expert testimony occupies a specialized category. Section 45 of the 1872 Act (and its successor provisions) permits courts to consult “experts” in fields such as science, art, handwriting, or fingerprint identification to form an opinion on technical matters. Courts have consistently held that expert opinion is advisory and corroborative rather than conclusive; however, when substantiated by robust scientific protocols, forensic evidence carries immense persuasive value.

2.2 Standards of Scientific Reliability: Moving Toward Objective Validation

Globally, the admissibility of expert scientific testimony has been shaped by rigorous judicial standards, such as the *Daubert* standard in the United States, which evaluates whether a technique can be tested, has been subjected to peer review, possesses a known error rate, and enjoys general acceptance within the scientific community. In India, while statutory provisions grant wide discretion to judges, appellate courts have progressively emphasized that expert testimony must be grounded in reliable data, standardized testing, and

verifiable methodology rather than subjective speculation.

A shining example of judicial receptivity to scientific innovation is the progressive acceptance of DNA profiling. In landmark rulings such as **State of Himachal Pradesh v. Jai Lal** and subsequent decisions, the Supreme Court of India recognized DNA technology as a highly reliable form of scientific evidence, provided that proper chain of custody, contamination prevention, and expert competence are rigorously maintained.

3. TECHNOLOGICAL MILESTONES AND POSITIVE ADVANCEMENTS

The years leading marked a golden era of technological integration within Indian forensic laboratories, significantly enhancing investigative capabilities and evidentiary precision.

3.1 Expansion of DNA Profiling and National Databases

DNA profiling underwent monumental expansion across Central and State Forensic Science Laboratories (FSLs). The establishment of specialized DNA divisions equipped with Next-Generation Sequencing (NGS) and automated polymerase chain reaction (PCR) instruments enabled forensic scientists to analyze minuscule biological samples—such as touch DNA, degraded bone fragments, and single-cell traces—with unprecedented accuracy. Furthermore, legislative and administrative momentum toward establishing a national DNA database facilitated cross-matching of cold cases, repeat offenders, and missing persons, transforming investigative efficiency.

3.2 Digital and Cyber Forensics

With the exponential growth of digital transactions, smartphones, cloud computing, and social media, cybercrime emerged as a major domain of forensic investigation. Specialized cyber forensic units across India made remarkable strides in data recovery, decryption, mobile device extraction, cryptocurrency tracing, and artificial intelligence-driven facial recognition. These tools enabled law enforcement agencies to dismantle complex cyber syndicates, financial fraud networks, and online child sexual abuse material (CSAM) rings with scientific certainty.

3.3 Forensic Pathology, Toxicology, and Ballistics Upgrades

Advancements in forensic pathology and toxicology—including liquid chromatography-mass spectrometry (LC-MS) and automated ballistic identification systems (IBIS)—greatly improved the speed and accuracy of homicide investigations. Automated ballistic comparison tools allowed forensic experts to match bullet striations and cartridge casings across national databases in minutes rather than weeks, linking weapons to multiple crime scenes.

4. ADDRESSING PROCEDURAL DELAYS: CHALLENGES AND POSITIVE SOLUTIONS

Despite extraordinary technological progress, historical challenges concerning procedural delays, infrastructure backlogs, and logistical bottlenecks have periodically impeded the timely delivery of justice. However, proactive administrative and legislative interventions have charted a remarkably positive

course toward resolution.

4.1 The Challenge of Laboratory Backlogs and Staff Shortages

Historically, a major systemic hurdle faced by criminal justice systems was the immense backlog of pending forensic exhibits awaiting analysis in state laboratories. Due to a shortage of accredited forensic scientists, inadequate instrumentation, and a surging volume of criminal cases, physical evidence—particularly DNA swabs and ballistic samples—often experienced months of delay before expert reports reached trial courts.

4.2 Legislative and Administrative Remediation

Recognizing these operational bottlenecks, the Government of India and various state administrations implemented transformative corrective measures:

- **Establishment of New FSLs and Mobile Forensic Vans:** The rapid establishment of new regional forensic science laboratories and the deployment of mobile forensic vans equipped with on-spot sample collection kits ensured that crime scenes were investigated scientifically from the outset.
- **Mandatory Forensic Investigation Reforms:** The enactment of the Bharatiya Nagarik Suraksha Sanhita (BNSS), 2023 (implemented in July 2024), introduced a revolutionary statutory mandate requiring mandatory forensic investigation for all offenses punishable with imprisonment of seven years or more. This provision legally compels investigating officers to visit crime scenes accompanied by forensic experts and videograph the collection process, drastically reducing evidentiary contamination and procedural ambiguity.
- **Capacity Building and Accreditation:** Institutional partnerships with academic universities and accreditation bodies (such as the National Accreditation Board for Testing and Calibration Laboratories - NABL) elevated the professional standards, training frequency, and certification of forensic personnel across India.

5. FUTURE PROSPECTS AND STRATEGIC RECOMMENDATIONS

Building upon the remarkable achievements realized, the forensic science ecosystem in India is exceptionally well-positioned to achieve global leadership through targeted strategic enhancements.

5.1 Integrating Artificial Intelligence and Machine Learning

The future of forensic analysis lies in the ethical integration of artificial intelligence and machine learning. AI-driven algorithms can accelerate facial recognition, automated fingerprint identification, handwriting analysis, and ballistic matching, reducing human error and expediting report generation.

5.2 Strengthening Continuing Legal and Judicial Education

Judges, prosecutors, and defense counsel must receive specialized, continuous training in forensic science. Bridging the gap between legal adjudication and scientific methodology

ensures that courtroom cross-examinations of expert witnesses are intellectually rigorous and scientifically grounded.

5.3 Ensuring Absolute Chain of Custody Integrity

Implementing blockchain-backed digital chain-of-custody tracking systems from the moment of crime scene collection to courtroom presentation will eliminate tampering risks and bolster absolute judicial confidence in physical evidence.

6. CONCLUSION

Forensic science represents the ultimate intersection of empirical inquiry and the rule of law, serving as an indispensable shield for the innocent and an unyielding sword against criminality. Through an exploration of evidentiary admissibility, scientific reliability, and procedural evolution, this article demonstrates that the Indian criminal justice system has embarked on a deeply positive, transformative journey. Landmark legislative overhauls such as the BNSS 2023, technological breakthroughs in DNA and digital forensics, and administrative initiatives to eliminate laboratory backlogs underscore a resolute national commitment to scientific justice. By sustaining these proactive reforms, embracing cutting-edge technological innovations, and fostering seamless collaboration between scientists and jurists, the legal framework will continue to ensure that truth prevails with absolute precision, speed, and fairness.

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